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Abstract

This dissertation comprises three essays on Infrastructure and Development Economics. Chapter I asks whether public infrastructure would continue to support economic development or else if Public-Private-Partnerships (henceforth PPP) might assume such role. I find that PPP can be effective alternative to conventional provision in developing countries where inefficiency gaps in planning, budgeting, allocation and time-schedule delays are important. Panel data results show that "animal spirits" are inversely related to financial security in terms of contract repudiation for French origin laws. Therefore, countries that engage on PPP with Multilateral Financial Support (MFS) have on average higher GDP pc and productivity levels compared to those who do not embrace on these programs other things being equal. Chapter II studies the role of infrastructure investments (public and private), State incentives (monetary and non-monetary) and technological patents in U.S high-tech firms with different value shares. I identify stylized facts from the U.S business slowdown (e.g. higher knowledge gap and lower competition between public firms). I propose a simple regional model in which workers have some kind of mobility and firms make use of monetary incentives (R&D subsidies) and non-monetary (diffusion of past policies). I find that both types of incentives coupled with non-residential private spending have a positive business "enabler" entrepreneurship effect on employment rates in top value-added industries while public highway expenditures display a "disabler" effect only in sectors with lower value share. Contrary to conventional wisdom, generous R&D tax-credits and user cost gains are associated to higher employment rates in bottom rather than top value-added sectors. When accounting for spatial effects, I find a "beggar the neighbour effect" in patents for bottom value-added sectors. The same trend is observed for wage industries. That is workers in high-tech sectors with lower value shares and marginal costs have on average better salaries while a higher policy score does not imply better salaries. Overall, the median worker in lower value-added sectors benefits more (on average) from these public policies as his/her salary is higher compared to those in top value-added sectors. Chapter III is an application of incomplete-market general equilibrium models where governments employ e-Procurement services (e-GP) for new infrastructure investments to reduce informational asymmetries. I construct a transparency measure for e-auctions and calibrate the model for Bangladesh a Least Develop Country. I find that household's accumulate assets under incomplete markets, capital stock increases but agent's consumption is lower. Results are consistent to early stages of development where households have lower earnings or else future uncertainty and lower transparency in government actions (e.g. corruption) enlarges precautionary savings.

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Santiago Caram

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To my mother Adriana, my biggest inspiration and supporter.

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"*Public services are never better performed than when their reward comes in consequence of their being performed, and is proportioned to the diligence employed in performing them.*"

Adam Smith, The Wealth Of Nations, Book V, Chapter 1, Part II.

Chapter 1

Public Infrastructure and Development: Past, Present or Future?

1.1 Introduction

During the last three decades there has been a considerable interest in measuring the effects of public infrastructure on economic development. One of the most important aspects for new projects is the one concerning the funding sources (e.g., debt, taxes or a combination of both). In this respect, given the financial constraints of large projects (e.g., a bridge in terms of works permissions and future stream of profits), the social return for entrepreneurs may not be enough to cover capital costs. If this is the case, then in-house (public provision) takes place and may complement the private market hand to boost economic development.

Nevertheless, public infrastructure (excluding military spending) has positive effects over development because it creates a link between economic agents (citizens, firms) and new profitable opportunities. More precisely, its provision is as a catalyst to economic growth by boosting firm's productivity, fostering new investments with positive effects onto employment rates and poverty reduction (direct effect). As a result, large infrastructure projects can be regarded as "big push" policies with "growth promoting" effects onto the economy (McNicoll, 2005, World Bank, 2005).

For what concerns quality, a better service is associated to positive externalities through lower financial constraints and higher investments rates. For instance, upgrades of the power grid system and/or maintenance of highway networks may reduce private physical capital costs, leading to more growth opportunities for the economy (Agénor and Moreno-Dodson, 2006). This means that private agents could use those additional resources to invest more in human capital and better health services. That is healthy individuals are more likely to learn new skills and study more with respect to individuals without a proper diet and with lower ability. On the other side, inefficient provision (e.g., highway potholes, water and electricity supply failures) may increase the cost of provision and reduce private productivity (Reinikka and Svensson, 1999).

Interestingly, a recent study from Fournier (2016) claims that all OECD countries with the exception of Japan, still have room for additional public investment (especially in health services and R&D projects). Although, there is also evidence of diminishing returns of higher stocks of public infrastructure. From policymakers' perspective the provision of public infrastructure is paramount because the performance of private firms (in terms of employment creation and productivity growth) and quality service, are inversely related to capital cost. Therefore, a lower quality service may prevent firms from internalizing their own comparative advantages and increase diversification. For those reasons, investment decisions might be even postponed, or reallocated to other countries (Lin, 2011).

Others instead, suggests a diametrically opposite approach with respect to traditional provision. Simply put, in light of the *"New Normal*[1]*"* (see, for example, Candelon et al., 2018) in a context of lower investment returns, higher risks and stagnant per capita growth rates in advanced economies, governments should embrace Public-Private-Partnerships (henceforth PPP)[2] as a complement of public procurement to increase private productivity and enhance economic development.

Nowadays, an important concern for policymakers is whether a single coarse of actions may boost productivity and private investment rates simultaneously and bring more opportunities to entrepreneurs in terms of new establishments, jobs and better salaries. In this vein, some scholars suggest a "growth lifting" strategy powered by private hands to overcome traditional provision (Lin and Doemeland, 2012). Expressed differently, the development of bottleneck-releasing infrastructure projects with self-financing sources. Thus, public projects which are not into the private sphere i.e., they do not replace nor replicate its actions (e.g., new telecommunication systems), would be exclusively in charge of private capitals. In this case, the solely attempt of competition could imply more losses than benefits, particularly if governments do not have fiscal resources. For example, if tax revenues are insufficient and at the same time, public sector is debt overhang, then, private provision could be a feasible alternative to assume the supply of public services.

Oppositely, a global strategy for infrastructure requires a proper policy design in many dimensions to raise private productivity and exports while reducing unemployment rates in

[1]The expression was first introduced by McKinsey and then by PIMCO authorities (Mohamed El-Erian) during March and May of 2009. The concept refers to the aftermath of the 2007/2009 Great Recession in which economies faced growth reductions coupled with persistent unemployment rates and selective bailouts (i.e., some banks went into bankruptcy due to risky behavior).

[2]For convenience, throughout the paper we employ the terms PPP and PPI i.e., Public-Private-Investments interchangeably.

developing economies. For instance, government consumption policies that focus only on the demand side, i.e short-run Keynesian policies of "digging a hole and filling it again" should be replaced by longer term growth projects (bottleneck-realising). In this manner, the interaction of public technical assistance coupled with a reasonable institutional background attracts private investments while boosting development indicators like labor productivity, income distribution, etc. However, this does not prevent that traditional stimulus spending may disappear, instead an integration process between both alternatives (i.e., PPP) seems more reasonable. For what concerns PPP, there has been a considerable growth and interest during the last two decades. The reasons of its outstanding proliferation and performance can be divided into two blocks: fiscal and institutional.

On the one side, countries with macroeconomic imbalances (e.g., persistent fiscal deficits, debt constraints, etc) are more likely to have PPP's. Naturally, PPP can alleviate infrastructure necessities by reducing the working-time schedules and foremost mitigating its financial burden. Therefore, bringing efficiency gains for societies as a whole (citizens, firms' and government's). On the other side, institutional quality measured by private ownership support, credibility and contract repudiation matters for speeding up the rate of new projects and quality service, especially in low income countries where the risk of expropriation is higher (see, for example, Esfahani and Ramirez (2003) and Yehoue et al., 2006). Therefore, productivity and investment rates will be higher in countries for which those institutional arrangements may have been more stable across time. Additionally, the degree of coordination between public and private sectors, can have sizeable effects on the efficiency side. For instance, higher levels of corruption may hinder synchronization among different state levels through excessive regulations, nepotism and rent-seeking activities. As result, productivity and investment rates may be compromised leading to lower possibilities of development.

The present paper asks whether public infrastructure would continue to support economic development or else if PPP might assume such role. In this vein, we support an "holistic" perspective using different indicators (e.g., institutional quality, the income distribution measured by the Gini coefficient and labor productivity) as it brings a broad picture of the link between infrastructure and economic development. In addition, we argue that infrastructure services should not be necessarily provided by only one actor (i.e., public sector) rather the private sector coupled with financial support may also be involved during the process. Along the efficiency arguments, a special concern is given to Public Investment Management Assessment (PIMA) and how to reduce (in)efficiencies in planning, budgeting, allocation and time-schedule delays

(International Monetary Fund, 2015). Addressing these bottlenecks is paramount because unreliable transportation services (lack of paved roads or highways), inefficient telecommunication networks and electricity services imply higher transaction and coordination costs, preventing firms from investing in new technologies, altering knowledge diffusion with a negative impact on workers productivity (see, for instance Shanks and Barnes (2008)). Finally, this paper makes use of bivariate cross-sectional regressions and panel data techniques to examine the relationship amongst infrastructure expenditures (public and private) and economic development.

Our empirical analysis based on trends and simple regression models provides the following results. PPP are an effective alternative to traditional provision of public services in low income and emerging and developing countries. The preferred sectors for PPP are electricity, water and sewage (i.e., sanitization) and roads/highways. Bivariate regressions show that multidimensionality matters: both (stocks and quality) have positive and significant effects over Real GDP pc, country's institutional quality and labor productivity. In the case of inequality, the relationship is negative across countries suggesting that countries with more infrastructure stocks and better quality service are more likely to have a better distribution of income. Interestingly, panel regression suggest that PPI couple with Multilateral Financial Support (MFS) can be an appealing alternative (compared to traditional State investments) to boost economic development as "animal spirits" are inversely related to financial security in terms of contract repudiation for French origin laws. In terms of policy implications, caution must be taken because doubling current investments may not lead to instantaneous improvements in living conditions if provision is not pass-through to a better quality service. The best policy for one country may not necessary be the same for another one. For instance, countries in which under-maintenance, budget execution failures, rampant corruption, nepotism and hidden costs have more weight (e.g., low income countries), policymakers efforts should be targeted in addressing those inefficiencies, increasing quality-service and transparency through new technologies (e.g., electronic procurement) as opposed to "digging a hole and filling it again". Overall, the paper provides a review of traditional questions that have been answered by extant literature and highlights future challenges for the infrastructure agenda.

The remainder of this chapter is structured as follows. Section 1.2 reviews the literature. Section 1.3 discusses the PPP framework, its main benefits and challenges with respect to conventional provision and the adoption of new methods like the PIMA approach. Section 1.4 presents updated evidence of infrastructure for many countries. Finally, the chapter concludes in section 1.5 and offers some policy implications.

1.2 Related Literature

Infrastructure provision can be explained from at least two perspectives. Keynesians argue that public investments can have different effects whether its duration is temporary or permanent. The first type will raise real interest rates and a demand pressure towards domestic production, but the final outcome will be a trade deficit. Conversely, the second type may generate an additional burden on tax payers to cover the amount spent (i.e., a wealth redistribution towards the public sector). Instead the public choice school claims that infrastructure must be regarded as the counterpart of citizen needs (e.g., transportation, health services, education, water supply systems, among others). Nonetheless, an efficient allocation of those services not only will depend on a fiscal constitution, but also on the State "incentives" to assign fiscal revenues to the "common good" and not the other way around i.e., personal reasons (Brennan et al., 1980, Chapter 7).

Public infrastructure literature explains that the decision-making process of new projects can have at least four stages (Estache et al., 2009). First, governments must decide whether or not public goods and services will be produced in-house (i.e., state "umbrella") or else, outside private entities assuming that role. This of course continues to be a traditional question of public economics because if governments rely on the private sector, the design of the contract is paramount. Second, governments must choose the owner, type of operator, a sequence of investments i.e., financing schemes to develop the project and to support future expenditures in the event of undermaintained stock and delegate the task to different agents. Third, if private actors assume the responsibility, then, the problem is addressed by the auction theory under different types of contracts which account market failures like hidden actions and missing information. The most important question in this step is how governments may prevent and detect collusion and corruption actions. Finally, after the commencement of a contract, governments must take into account possible ex-post adjustments in the event of unforeseeable issues i.e., the likelihood that external factors like bankruptcy of private contractors or country's sovereign debt default. These aspects are important because projects have a long-term duration and future uncertainty may undermine the potential benefits of infrastructure investments.

For what concerns the empirical evidence, it is well-established that the effect of infrastructures expenditures over development is positive. Focusing on the positive side, better transportation networks (e.g., new highways, the replacement of old rail-tracks along with faster locomotives) effectively reduce transportation costs. Hence, public expenditure would be consider a "complement" to private production. Better infrastructure services provided by government's allow private firms' the possibility to fully exploit the resources given and increase labor productivity. Thus, less financial and operational constrained firms may expand the output, investment more and generate positive spillover effects to a country and its regional economies.

One of the first studies was provided by the seminal works of Aschauer (1989*a*,*b*). He investigates the effects of public infrastructure over private productivity for the U.S through the lens of aggregate production functions and applied the neoclassical approach to empirically asses the impact of public capital over private productivity. His results suggest that higher stocks of public investment in the U.S "crowd out" private investment on capital goods and ultimately, affect the output.[3] Conversely, "core infrastructure" should be regarded as a complement because it increases private marginal productivity; hence, a "crowd in" effect. Overall, the final outcome over the economy will depend on which of these two forces prevail.

Moreover, in a similar paper Aschauer et al. (1989) finds a positive relationship between public to private capital ratio and private productivity. To be precise, a 1% increase in the proportion of public to private capital raises 0.39% private productivity, ceteris paribus.[4] Additionally, his evidence confirms two things. First, capital productivity is procyclical (i.e., higher elasticities) which means that depending on the phase of the economic cycle, the capacity utilization rate can be negative (contractions) or positive (expansions).[5] Second, causality links —running from public capital towards private productivity— are present, not only for the whole sample but also for specific industries as well (e.g., transportation). Third, in G7 countries the composition of public consumption and public investment influences growth rates. Again, the presence of direct and indirect effects over productivity and ultimately output are substantial. Simply put, the former is transmitted through public services provision (e.g., trains, airports, etc.) which are necessary for private production. Consequently, this channel ties private household production and international markets. As for the latter, public infrastructure can generate complementaries between public capital stock and private capital returns. However, he noticed that apart from the previous effects, consumption in those countries may have surpassed capital accumulation, putting more pressure on productivity growth.

Despite finding positive effects associated to additional capital stocks and identifying infrastructure main channels, Aschauer results have been cast doubt. As Munnell (1992) claims, a natural but critical question arises: How can returns from public investments are able to

[3] The mechanism is straightforward: national rate of capital accumulation raises more than the level chosen in the previous period. Therefore, households decide to switch from one good to another (public investment returns are no different from private ones).

[4] His econometric results were also robust to the choice of different sample periods (e.g., 1949-67/1968-85, 1953-1985 and 1949-1981) and a different estimation method (2SLS).

[5] Notwithstanding, cross-country evidence found by Ford and Poret (1991) depicted that the relationship between infrastructure and productivity may be at lower frequencies than the behavior of business cycles.

generate a greater impact on private production and not the other way around? More recently, the works of Romp and De Haan (2007) and Bom and Ligthart (2008) confirmed that earlier estimates of the rate of return of public capital of Aschauer were too large and they offered two explanations: model misspecification —due unspecified cointegrating relationships— or either spurious links given the type of data employed (aggregated time series). Interestingly, Eberts et al. (1990) previously had argued that regardless the type of studies (regional or country), researchers should take into account the unobserved heterogeneities, firm's location, State incentives (e.g., federal grants) and complementaries amongst public/private capital and output in both directions.

Likewise, regional evidence is not exempt from drawbacks. For instance, using data at industry level for U.S economy, Hulten and Schwab (1991) did not find evidence of technological spillovers when regional governments invest in public infrastructure. In plain words, return rates of public projects are not as outstanding as Aschauer evidence due to cross-state heterogeneity. In another industry study for regional economies, Hulten and Schwab (2000) applied a growth decomposition to examine public capital contribution to Total Factor Productivity (TFP) growth for the manufacturing industry. Additionally, authors performed a correlation analysis between TFP and infrastructure (both in levels) while controlling for the capacity utilization. Again, their results indicate that infrastructure is insignificant when regional fixed effects are present (although with time effects, public capital spillovers are indeed significant).

Nonetheless, two important issues are worth mentioning. First, infrastructure is not a choice variable for firms; thereby, the optimization calculus between social benefits and social costs does not hold. Second, public user cost is difficult to measure given the fact that public goods are subject to common consumption and congestion (e.g., the construction of bridge in one region reduces transportation costs).[6] For those reasons, infrastructure effects have been studied under two different approaches.

On the one hand, advocates of the production function approach (APF) implicitly argue that the problem is sequential: productive inputs (e.g., labor) are exogenously determined and firms optimize their output based on the availability of these factors. In plain words, quantities are given or factor supply is perfectly inelastic. As a result, infrastructure is circumscribed to evaluate whether public capital additions increase firms' output. Although, APFs are not exempt from drawbacks. First, output elasticities obtained under this methodology disregard firms' behavior. Second, the production technology is not fully specified. Therefore, growth estimates may suffer from overestimations.

[6] An strategy applied in the past was to regard the return of a public bond and then apply it to the investment deflator to generate the base user-cost (Munnell et al., 1990).

In order to overcome the empirical difficulties from above, Holtz-Eakin and Lovely (2017) applied the APF approach within a general equilibrium framework. Their econometric results indicate that the number of varieties (i.e., quantity of establishments) have a larger (positive) impact on manufacturing output rather than firms scale production channel (through lower fixed or variable costs). Hence, the authors suggest that infrastructure analysis should shift towards the composition of activities instead of the level of particular industries.

On the other hand, those who cling on to the aggregate cost function methodology (ACF) suggests that input prices in a competitive economy are given (perfectly elastic) and can be treated as exogenous.[7] Consequently, infrastructure effects are disentangled from a cost-efficiency contribution to output. Simply put, infrastructure allows to reduce the use of input factors; thereby releasing more resources to firms. Hence, when infrastructure investments take place, a decline in variable inputs occurs, allowing firms' to produce more with a given input (i.e., cost saving). For instance, applying the ACF, Morrison and Schwartz (1996) find significant cost-saving effects in most of the U.S regions (between $160,000-180,000 USD on average) but almost twice in the south. Yet, they argue that infrastructure involves a cost-benefit analysis and above all, firms' behavior and technology must be considered. In plain words, shadow values from both types of capitals (public and private) should be compared with respect to their opportunity costs.

Interestingly, Gramlich (1994) had already tackled and answered that same question. To be precise, he claimed that the problem was not about infrastructure "shortage", but rather a different policy implementation. From his point of view, there are four ingredients that must be included onto any empirical study: 1) Infrastructure assessment (engineering); 2) Political effect (voting); 3) Rate of return of public provision (externalities) and 4) Productivity estimates (econometric approach). The first one is planning, i.e., the provision of new highways as well as the composition of budgets. The second aspect is related to bounded rationality, i.e., voters do not know the "true state" of public capital. Accordingly, vote-maximizing politicians may use privileged information to generate a false sense of shortage by proving less than the corresponding amount. In that vein, the work of Cadot et al. (2006) finds that transportation provision for the French economy may be explained by electoral incentives. Finally, as for the last two arguments (3 and 4), caution must be taken because agencies could load the dice in favor of infrastructure spending, commonly known as "pork-barrel". As a result, public capital elasticities from econometric models could suffer from this bias.

[7]However, as Haughwout (2002) claims, both approaches (APF or ACF) cannot capture adequately the marginal productivity of public capital as regional factor markets are more complex than perfect competition assumptions. Moreover, firms and households move across regions; hence factor prices (wages and land) will vary in response to infrastructure policies.

Furthermore, infrastructure has also been applied to endogenous growth models. On the one side, adding government purchases as another input of the utility function allows to capture the effects of public goods over private productivity.[8] Notwithstanding, government size as well as the tax structure could also determine different growth trajectories for the economy. For instance, countries in which public expenditures represent a higher proportion from national budget would require an additional burden (possibly by means of distorted taxes) towards taxpayers. Thus, reducing private incentives for new investment projects.[9] In that line, if productive expenditure exceeds a certain level —given by the "Barro rule"—, then additional distorted taxation will be necessary to finance other non-infrastructure projects, reducing income growth.[10]

For what concerns the other side, Barro (1991) suggests a quality distinction within infrastructure provision. In the worse case scenario, if infrastructure expenditure is unproductive, then it will have a negative impact on saving rates due to the increasing tax burden required to finance that project. Accordingly, individuals will have less incentives to invest which leads to lower growth rates.[11] Hence, any decision regarding infrastructure expenditures involves a two step analysis: First, the degree of complementarity or substitution between the existing services and its impact over the private sector. Second, the source of finance (e.g., debt, taxes or both). This step is not trivial because public infrastructure expenditures with debt funding or taxes are not neutral.[12] Third, cross-country differences are primarily based on the optimization assumption. If governments optimize, marginal cost (one unit more of public expenditure) and marginal revenues would be equalized, then, countries will behave similarly (from the microeconomic point of view). Yet, empirical evidence points out that "Wagner Law" still holds for some type of services (e.g., education and transfers) and also "too much or too little provision" can have a sizeable impact on the economy. Particularly, the effect is significant for transfers, where a rise by 0.5% in the public spending/GDP ratio boosted GDP pc by 10%.[13] Overall, the empirical evidence of Barro is in line with those previously found by Aschauer.

[8]Congestion patterns —commonly associated in public economics were disregarded in his analysis. Yet, they can be easily introduced, see for example Ott et al. (2006).

[9]According to Auriol and Warlters (2012), when tax distortions are significant, countries may face a cost of public funds close to 37%.

[10]Barro's rule states that the share of government expenditure in GDP and thus, the tax rate should be equal to aggregate output elasticity.

[11]Notwithstanding, if government expenditure generates a reduction in property right costs, the marginal tax rate can be drastically reduced. As a result, saving rates will be higher and on aggregate, it would imply additional resources to invest into the economy.

[12]In a world with no distortionary taxation, it does not matter where government purchases come from (Ricardian Equivalence). Yet, governments usually increase their infrastructure needs by applying distorted taxes. As a result, households take that information into their own maximization calculus. Hence, public provision may suffer because resources may not be sufficient to finance such expenditure.

[13]Adolf Wagner was the first one to observe the relationship between public expenditure and income (Wagner, 1890). Indeed, his theory states that as countries develop, industrial countries will tend to have a higher share of public expenditure in gross national product. As a matter of fact, Peacock and Wiseman (1961) proved that the link also holds for any country.

Along the fiscal arguments, policymakers should not disregard the multiplier effect over output (Barro, 2009). Here, two different scenarios arise (i.e., a 1.0 coefficient and its converse a 0 value). In the first case (perfect multiplier), public infrastructure provision would not require any effort (in terms of opportunity costs) to society because it would be essentially free of charge. Therefore, aggregate demand would have a one to one relation with public expenditure regardless the type of public service provided. In the second case, (a zero multiplier), the social cost of public infrastructure will be maximum and society would have to "sacrifice" aggregate demand components (i.e., current consumption, investment, net exports) which indirectly would hit productivity rates (e.g., constrained firms' through the adjustment cost function) because resources will be lower. The 0.8 coefficient suggested by Barro seems to be in line with the review made by Ramey (2011) in which she summarized the majority of empirical studies (0.8 up to 1.5).

Additionally, policymakers' should regard the "starting point" of the economy (i.e., troughs, expansions, peaks or contractions) because the extent of capacity constraints are critical.[14] Nonetheless, in spite of multiplier's magnitude, the most effective approach is a cost-benefit analysis —from a social point of view— and simultaneously focus on people's incentives to work, save and invest by reducing the burden of distorted taxes (e.g., corporate income tax). In this way, public infrastructure investments can have positive spillovers onto productivity, employment, and ultimately growth. Moreover, if the economy is depressed, then, investment returns will be sufficiently large meaning that welfare of both present and future generations can be improved (Bivens, 2012).

Furthermore, an important task for the empirical analysis of infrastructure and development is data reliability. In that line of research, due to the extensive works of Canning (1999), Canning and Bennathan (1999), cross-country stocks comparisons allowed researchers to unpack infrastructure real effects beyond the standard theoretical models using different indicators like the percentage of paved roads, electricity-generating capacity and water consumption all of them positively correlated to country's income level. Similarly, Fay (1999), Fay and Yepes (2003) were the first ones in considering infrastructure demands and performing panel data regressions in a first step to then use in a second step the estimated coefficients for demand projections. From the econometric point of view, this is possible because infrastructure adjustments (stocks) tend to be slack over time. In broader terms, authors show that the required investments for the entire world would have been USD 849 billions for the years 2005-2010. For developing economies, infrastructure investments should have increased in USD 465 billion per annum for the same

[14] The provision of public infrastructure during contractions periods yields a completely outcome than in times of expansions.

period. In terms of sectoral allocation, telecommunications: both mobile and land lines might have increased (USD 190 billions), electricity generation (USD 139 billions) and finally roads (USD 88 billions). Although, it is worth mentioning that power generation sectors have more weight on low income countries. Thus, fiscal efforts must be doubled. Conversely, high-income countries would require almost 17.42% less resources (USD 384 billions) than developing ones.

Nevertheless, infrastructure accounts several dimensions. As a result, cross-country research is usually complemented with regional analysis and development measures such as productivity growth per worker, Gini index, electricity, telecommunication, water and sanitation per capita consumption, among many others). Studies show that better quality service of infrastructure investments is associated to potential spillovers, particularly for poverty alleviation in African economies (see, for example Estache (2006) and Estache and Fay (2007) and Fay et al., 2011). Moreover, these authors suggest a two dimension distinction for infrastructure quality. The first one includes productivity measures such as output/number of users (a common practise in water and telecommunications services). Certainly, this is an objective metric which can be easily obtained if data is available. The second one is cost padding. In other words, if private costs are not recovered, then, operators may not be able to afford the excess of demand because of the mismatch between tariffs and production services. Therefore, quality choices involve technical efficiency and willingness to pay for a good quality service. For example, in some African regions, citizens should assign no more than 15% of their salaries to public services (5% water and sanitation, 4% energy and the rest on transportation) which in most cases may not be possible.[15]

Other studies concentrate on the macroeconomic, fiscal and efficiency sides. For instance, using household survey data Briceño-Garmendia and Klytchnikova (2006) find that the gap between the poorest and richest 20% is systematically stronger in African countries where the mismatch between fiscal revenues and infrastructure allocations is considerably larger. Along the same fiscal efficiency lines, Briceño-Garmendia et al. (2009) find three major sources of inefficiencies for 24 Sub-Saharan countries: under-maintenance, budget execution failures and hidden costs. In the first case, about half of that sample suffer from shortfalls of 40% in the road sector. The second issue is even more dramatic in these countries where almost 50% have not been executed due to allocation failures. Finally, hidden costs can absorb up to 1.8% of GDP depending on the sector under analysis (e.g., power, water and communication). Therefore, authors suggest that underpricing is the best policy to increase efficiency and reduce costs without the need to increase budget allocations.

[15]The rule of thumb was introduced by the World Health Organization. However, it is extremely difficult to measure it due to limited data, though some surveys actually do report those type of expenditures.

Nonetheless, the dichotomy between public and private provision has lost relevance, instead pragmatism predominates. Nowadays, the focus is on quality service because there is a strong correlation among a country's average per capita income and different socioeconomic indicators like water sanitation, access to health. For example, Galiani et al. (2005) claim that expanded access to water and sanitation systems can reduce child mortality by 8% on average. Accordingly, policies framework should be redefined at preventing low income countries enter into vicious circles (poor quality of infrastructure services - productivity growth stagnation - growth opportunities hindered). From a policymaking perspective the following questions have been on table during the executive program of World Bank (2006). What is the best course of action to enhance productivity, provide affordable and good quality services? Is it possible to increase infrastructure stocks and reduce income inequality? How can be managed private incentives? Do countries have the necessary institutional conditions to support private market initiatives? Can corruption clauses influence the proliferation of infrastructure projects?

Although, new econometric techniques are now capable of answering the majority of the above-mentioned questions, empirical research on this topic suffers from three major problems: 1) non-linearities 2) common factors and cointegration among variables 3) endogeneity, reverse causality and simultaneity relations. In addition to the above-mentioned challenges, very few countries collect and report data on infrastructure investments and quality service. In order to overcome missing information, household surveys are necessary, but the scope of analysis is limited.

To address the first issue, earlier studies find that the maximum marginal productivity is achieved when infrastructure networks are sufficiently but not fully developed (Canning and Bennathan (1999) and Candelon et al., 2013). Interestingly, authors find that non-linearities in sectoral expenditures (e.g., water, sewage, roads, electricity, telecommunications, etc) depend on the network's completeness. Accordingly, the marginal return of new investments will be higher (lower) when the level of physical infrastructure is complete (incomplete). For those reasons, in developing economies the provision of basic services like access to fresh water and sanitization systems is essential while in more advanced economies specialization may be not be a priority as these services are already granted to the majority of population. The second and third issues are more challenging, because cointegration (long-run) relationship can be contaminated with endogeneity. For instance, Serven (1999) develops a simple model for India using disaggregated public capital data to examine the short and long-run responses while accounting for heterogeneity and weak exogeneity.[16] Results for the long-run show a positive

[16]This terms refers to the case when models contains no cointegration terms (long-run) or in the short-run analysis when the covariance between the disturbance between both models (structural and marginal) are equal to zero (Urbain, 1993).

effect of public infrastructure on private capital stock and an adverse effect of non-infrastructure capital after controlling for capital good prices and private credit.

For what concerns endogeneity, Calderón and Servén (2004) examine the relationship between infrastructure and growth through the use of the dynamic panel data techniques (Arellano and Bond, 1991). Their empirical analysis brings two important contributions. First, the construction of a synthetic infrastructure stock index in two levels: quality service and stocks. To be precise, authors find that a one standard deviation increase in the index would raise the median country's growth rate by 2.9%, whereas an analogous increase in the quality index would increase growth rates by 0.7% approximately. Therefore, the combination of both infrastructure dimensions would lead to a growth stimulation of 3.6% points. Yet, point estimates of telecommunications (main lines or total lines) would boost growth rates by 2.6 and 3.1% respectively whilst in the power generating branch, increments would be confined to 1.7%. Second, authors unpacked infrastructure effects on growth and income inequality through the Gini coefficient and provide pairwise correlations. Results indicate a -0.49 and -0.54 significant relation using the infrastructure stock index. Likewise, the Gini coefficient is also negatively correlated with infrastructure stocks in communications (-0.39), power (-0.44) and transportation (-0.48 roads and -0.57 rails). The same pattern is observed for infrastructure services: -0.34 (telecommunications), -0.26 (power) and transportation (-0.55). Overall, results show that both dimensions (stocks and quality services) have a negative and significant impact on the Gini coefficient. A diametrically opposite approach is the use of simultaneous equations to overcome identification problems between infrastructure and growth. In other words, using the initial income as instruments in simultaneous equations may isolate infrastructure from growth and reduce overestimation problems and reverse causality because parameters are taken as constant functions, allowing researchers to capture the factors that cause time-varying heterogeneities (Esfahani and Ramirez, 2003).

Last but not least, the works of Calderón and Servén (2010*a*,*b*, 2014) empirically assess the link amongst infrastructure, growth and inequality. To be precise, these authors combine cross-country regressions with a comparative analysis between Sub-Saharan Africa (SSA) and Latin America (LAC's). In the SSA region, the problem of both poor stocks and quality service is mostly explained by a geographic disadvantage and stagnant growth rates. For those reasons, addressing infrastructure necessities in SSA countries at both margins is a critical task for policymakers, especially for quality service where its performance has worsened in absolute terms. Along these lines, the authors argue that the negative relation holds (e.g., the normalized median of the synthetic index for SSA was -1.4 on average during 1991-5). In the LAC region, the situation is albeit far from perfect. Despite having a natural comparative advantage in agriculture, infrastructure quality in LAC's is rather weak and with large gaps among countries, particularly in land transportation where the percentage of paved roads by 2000-5 were less than 25%. Moreover, the pace of growth on quality services is stagnant from 15% in 1981-5 to 23% in 2001-5. In the case of stocks, power electricity generation has fallen behind almost three times (1.02) compared to high income countries (3.96) whereas in other items (e.g., telecommunications) the gap has narrowed over time due to the massive growth in the number of mobile phones (0.88 during 2001-5 against 1.92 in East Asian countries for the same period). In the case of inequality, the same authors claim that speeding up infrastructure projects comes at costs. For example, cutting in half the infrastructure stock gap between SSA countries and those of comparable income levels in other regions, could require as 15% of GDP of additional investment, plus potentially additional sacrifices in terms of aggregate demand. Whilst in LAC's the situation is a bit different, infrastructure development offers a considerable potential to speed up the pace of growth and poverty reduction. In that vein, total infrastructure investment (power, telecommunications, roads and railways) as a percentage of GDP, collapsed during the "lost decade"[17] and ever since, the fall has not been reversed due to weak regulatory frameworks and latent though higher risks of expropriation. For those reasons, governments ended up with outstanding costs and contract renegotiations.

Finally, more recent studies concentrate on both endogeneity and heterogeneity of parameters and production-functions. For example, Calderón et al. (2015) use an augmented infrastructure production function which relates output per worker to non-infrastructure physical capital, human capital inputs so that network and congestion effects can be tested. In addition, authors addressed heterogeneity by removing unobserved common factors (i.e., testing cross-sectional dependence), imposing long-run homogeneity to finally apply the Pooled Mean Group (PMG) estimator.[18] Results fail to reject the null hypothesis of homogeneity. Therefore, regardless the type of heterogeneity (unconditional, conditional, level of development or population size), the marginal productivity of infrastructure is higher in countries whose relative stock of infrastructure is lower, other things equal. When authors apply the Common Correlated Effects (CCE) (Pesaran, 2006), results hold. For what concerns PPP, empirical literature has grown massively over the last three decades. For that reason, the next section will make brief review highlighting the main benefits with respect to coventional provision.

[17]The term lost decade is known as a period of higher levels of public debt along with stagnant growth rates.

[18]The PMG is an intermediate case of the dynamic fixed effects estimator. From the practical point of view, it provides flexibility to the short-run coefficients, speed of adjustment and error variances to differ across cross-sectional units (Pesaran and Smith, 1995).

1.3 Public-Private-Partnerships

In light of the "lost decade" episode that took place in Latin American countries, a new paradigm shift took place: Public-Private-Partnerships (PPP). Indeed, its growth is undeniable, since the beginning of the 90's, these type of investments have increased steadily at an average pace of 13% a year (Fay et al., 2011). Overall, PPP volumes prevailed despite the financial crisis in 2008-9, but conditions become more stringent (in terms of financing sources).

Yet, does PPP brings more efficiency for society? What are the reasons behind its increasing participation amongst developing countries? What are the most preferred sectors? What is more, does institution quality and macroeconomic financial stability affect the proliferation of future PPP? Is it possible that both types of operators simultaneously coexist?

The questions from above have been answered by many researchers during the last decades. For instance, the well-known x-efficiency theory developed by Leibenstein (1966) highlights that inefficient public administrations are more prone from both distortionary government interventions and a higher degree of bureaucratization. For those reasons, PPP may be an appealing alternative to reduce both inefficiencies (at a micro and macro level) by bringing more competition into the market.

Furthermore, what drives the participation of the private sector? The answer relies on many dimensions: exchange rate risks, political instability may influence the investing decision in particular infrastructure projects (e.g., telecommunications). Additionally, the implementation regulatory frameworks is an important factor for the investment process. As we know from the neoclassical investment model (for more details see Hayashi, 1982), firms decisions are more likely irreversible, in the sense that once the (physical) capital is sunken into the economy, firms expect to recover the initial investment. Thus, adequate regulatory frameworks preventing expropriations or distortionary interventions, may strengthen the quality of institutions and most important could bring more private participation. Interestingly, the most preferred sectors for this type of investments are telecommunications, electricity and roads projects (Fay et al., 2011). However, when we breakdown by income group, these type of investments are more likely to occur in low income compared to high income economies. For instance, in low income countries private operators are mostly concentrated on the supply of electricity, water or rail services.[19] But, the largest sector is still telecommunications with more than 60% of countries relying on private suppliers. Overall, PPP flows accounted less than 1% of GDP, regardless the

[19]During the 90's, Latin American countries adopted several privatization process, particularly in the energy industry, telecommunications and pension system. While the last one is out of the scope of this paper, the evidence states that the public sector slowdown its investments in the hope of a compensating effect from private hands. Unfortunately, and even though access costs reduced dramatically, the net effect was negative due to a weak regulatory framework and lack of controls.

group of income (0.85% of GDP for lower and middle income and 0.69% for developed ones) during 2000-5 period.

For what concerns the empirical evidence, the work of Yehoue et al. (2006) was one of the first ones in exploring the determinant of PPP both at country and firm level. As a matter of fact, they test several channels: 1) government constraint; 2) political environment; 3) market conditions and macroeconomic stability; 4) institutional quality and legal system; 5) past PPP experiences and 6) private participation extent. Results show that the market condition channel is the most relevant as large markets allow customers to increase their purchasing power, attracting more PPP. Another important channel is given by the macroeconomic conditions. For instance, the presence of instabilities (fiscal deficits, heavy tax burden and exchange rate volatility) reduces the number of PPP. When testing the political channel, evidence shows that ethnically fractionalized societies, political biases, and the lack of checks and balances from the legislature may discourage the formation of PPP. Turning to the third channel, results indicate that countries with lower inflation rates and more stable exchange rates are more attractive for PPP (Dailami and Klein, 1999). In addition, countries in which currencies are stronger (in terms of purchasing power) are more likely to have PPPs because aggregate demand tends to be greater. Another important venue which explains the proliferation of PPP is institutional quality (North, 1991, 2003). In fact, as Pistor et al. (2000) suggest, the effectiveness of legal institutions matter most than law on the books. In plain words, countries in which the quality of regulations to investors are: certain and stable (given by the rule of law), have on average stronger institutions. Thus, increasing the incentives for investors to join PPP. Likewise, the likelihood of future PPP experiences will be higher in countries with past PPP experiences.

Conversely, countries with a lower respect of institutional arrangements are less likely to attract PPP. For this channel, authors claim that the influence of lower corruption levels and higher respect of contracts through the rule of law as main drivers of future PPP. Although results are mixed for specific sectors like energy and/or countries with higher expropriation risks which are forced to offer attractive returns in exchange of PPP investments. Finally, the above-mentioned authors test the extent of private participation at industry level. However, results show that ICT investments are more innovative and provide advanced technologies compared to transportation sectors. Therefore, PPP engagements tend to be higher in the telecommunication branch, supporting Besley and Ghatak (2001) hypothesis for which the extent of private participation depends on the quality of public goods or services (impurity level) and the required technology of the production function. Therefore, if public provision does not meet the minimum expectations it should be gradually replaced by private hands.

A diametrically opposite approach of PPP growth focuses on the financial risks and funding sources. On the one side, Engel et al. (2010) develop a simple model to show that it is optimal to transfer demand risk to governments. The reason is straightforward: PPP involve large investments and naturally longer time horizons (e.g., 30 years). Thus, by assigning it to the government, the perceived risk to external lenders falls. But, if there are no demand risks (projects which are based only on availability payments), finance rates charged PPP must be higher than the ones charged on government debt. Indeed, the associated risk to construction costs of a PPP will be similar under a price cap construction contract. Accordingly, they suggest that both types of risk (failure and uncertainty) should be shared to provide strong incentives, reduce costs and enhance efficiency.

On the other, Yescombe (2011) states that the proliferation of PPP is related to the development of project finance (i.e., a promise of future payoffs). Certainly, given the extent of some projects (e.g., hospitals, highways), the majority of private operators usually consider leverage as their major founding source. In addition, during the life span of the project, private partners receive a stream of payments to compensate the initial investment (i.e., capital expense). However, if the project fails, then, the remaining assets (to be transferred) will be illiquid and will have little value. Accordingly, projects must be very profitable to compensate the sponsors (i.e., main funding source of private partners) although at later stages, sponsors delegate the funding to third party passive investors.

All in all, PPP has received the same treatment as conventional public procurement. Indeed, PPP contracts have similar implications for the intertemporal budget as public provision. Unlike privatization, in which the project is sold for a one-time payment and all risk is transferred to the firm, PPP and public investments differ on two aspects: revenue timing and funding composition (e.g., private partners usually have sponsors). In fact, hardly any difference exists with regards the intertemporal budget constraint. To put the discussion into context, the timing works as follows: the government delegates the provision to private a party, then, operation and maintenance takes place along with the collection of revenue flows. Eventually, at the end of the life contract, assets are reverted (transferred) to public ownership. Finally, cross-country experiences suggest that PPP can be an attractive alternative for developing countries with lower stocks of infrastructure. However, there is no such thing as a free lunch. Indeed, it is a challenging task because for some groups of countries (e.g., Caribbean), projects are often too small to attract global investors and the same time, governments do not have the required capacity nor the necessary funding to afford such investments.(Queyranne et al., 2019). For those reasons, Multilateral Financial Support (MFS) may be necessary. Overall, and despite such difficulties, PPP can crowd-in private investment, generate efficiency gains for society, mitigate fiscal costs and reduce risks.

Public Investment Management Assessment (PIMA)

In light of the existent empirical evidence on conventional procurement and PPP two things are certain. First, the impact of infrastructure over economic performance is mediated by several factors (e.g., level of economic development, structural characteristics of the economy, quality of institutions, geography and even climate). Second, public infrastructure should be regarded under a multidimensional approach (i.e., stocks and quality service).

Earlier studies explain the importance of corruption, check and balances and competitive elections in determining the quality of public investment (see, for instance Tanzi and Davoodi (1998) and Keefer and Knack, 2007). For instance, in the aftermath of corruption scandal in the city of Milan, rail, subway and airport costs (in terms of one kilometer), fell by 52%, 57% and 59% respectively. Thus, political "grand corruption" matters in public infrastructure provision whereas the latter suggests that countries with lower quality of institutions, public infrastructure are used as rent-seeking vehicles: from pork-barrel in the U.S to "white elephants" in Nigeria, public investment has always been used for purposes far from growth (e.g., political support and even corruption at the highest executive levels).

Recent evidence for MENA and CCA countries highlight the importance of stronger institutions and infrastructure efficiency (Albino-War et al., 2014).[20] Authors point out that actions should be complemented with more transparency, a revamp framework and management assessment. In this vein, a report from the International Monetary Fund (2015) revealed large efficiency gaps in public infrastructure provision: 13% in advanced economies, 27% in emerging economies up to 40% in low income ones. Accordingly, in order to reduce those inefficiencies, the IMF designed the PIMA framework. For instance in Figure 1.1, the PIMA evaluates 15 institutions that shape public investment decision-making at three stages:

The first stage (planning), requires sustainable levels of investment across the public sector. In this case, fiscal rules, plans (national and sectoral), coordination, monitoring and regulation of PPP are evaluated for each participating country.

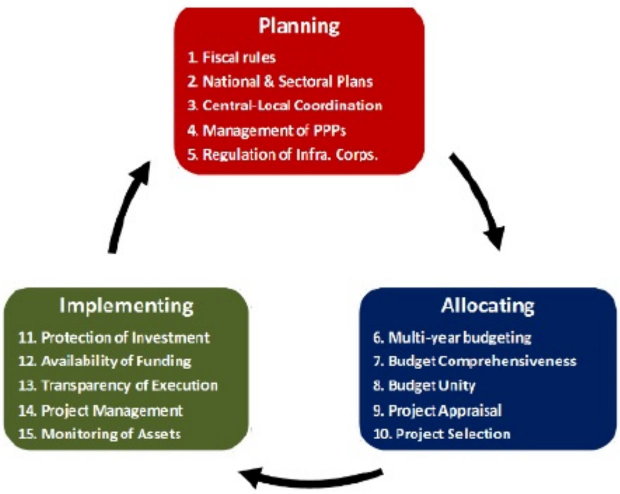
The second one (allocating), is much more accurate because investment projects should be targeted into the right sectors. To be precise, budgets must have a multi-year format taking into account several factors: funding sources, political component and legal documentation (e.g., by

[20] Middle East and North Africa (MENA) encompass the following countries: Algeria, Bahrain, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen. While Caucasus and Central Asia (CCA) is composed by: Azerbaijan, Kazakhstan, Uzbekistan, Turkmenistan.

the legislature), current and future maintenance costs and finally potential risks based on the final selection of a project.

Finally, implementation comprehends budgeting time-schedule (i.e., projects must be finished on time and within budget constraints). Particularly, this stage regards the protection of the investment made (the executive power cannot interfere into the assigned budget), availability of funding (every expense is carefully planned and forecasted), transparency (projects are monitored and tendered in competitive processes), solid management (projects are standardized and adjusted based on particular guidelines) and last, asset monitoring (depreciation is recognized and reported in financial statements).

FIGURE 1.1: PIMA Framework



Source: International Monetary Fund (2015)

Overall, and based on each subset of categories, countries are given a score between 0 (no key features) and 10 (all features in place). For instance, in panel (a) Figure 1.2, the overall scores are displayed by income. Clearly, advanced economies have on average stronger institutions than the rest of the groups. Nonetheless, sectoral planning, coordination and multi-year budgeting scores in emerging and low income economies are at least as good as in the most efficient ones.

Similarly, in panel (b) Figure 1.2, the scores are split by regions. Indeed, geographic region scores indicate stronger PIMs in Europe and Latin America whereas Middle East and Central Asia countries display weaker results, mostly characterized by considerable variation in the Asia-Pacific region.

Accordingly, what are the benefits of the PIMA approach? The answer is straightforward: by applying an integral strategy, countries could reduce inefficiency gaps identified above by two-thirds on average for low income and developing countries. On the one hand, not only it provides macro-fiscal framework, but also it allows the integration of investment planning in medium-term budgeting, coordination across different governmental levels as well as private participation in the provision of public infrastructure.

In addition, PIMA approach facilitates public asset monitoring, project appraisal and selection to low-bottom income countries. Although, good policies take time because the necessary institutional changes, cannot be introduced overnight. As a matter of fact, not only it requires legal and institutional changes, but also the development of new skills and capacities as well.

Furthermore, substantial changes have been done to the original PIMA framework (Figure 1.3). Indeed, improvements were made with a more in-depth focus on four major aspects of a country's PIM institutions: 1) maintenance; 2) procurement; 3) independent review and 4) enabling environment.

The first component is critical because public capital is an asset that provides benefits for many years beyond the initial investment. Therefore, the estimation of the required expenditure brings more efficiency to capital allocation. As a result, the revised framework includes a specific institution on maintenance.

The second one is also important because it involves technical efficiency in public spending. As a consequence, the updated framework recognizes the importance of procurement by establishing a dedicated PIMA institution devoted to it.

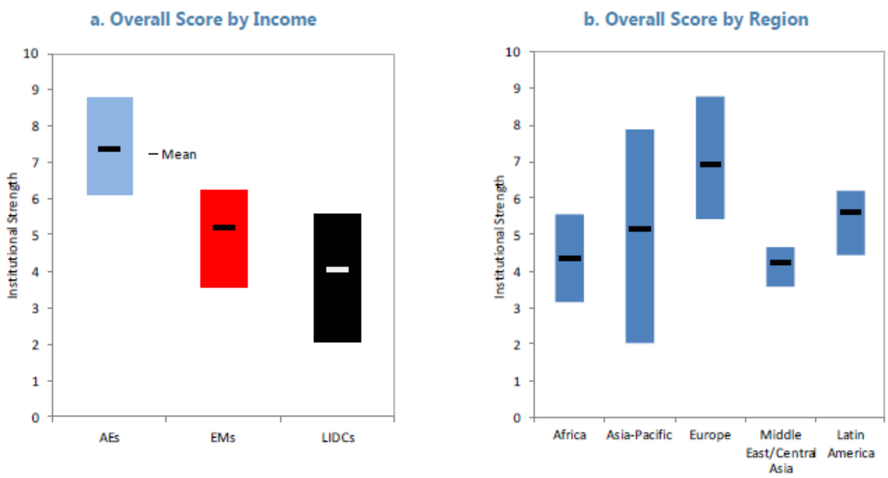
The third one, acknowledges the importance of counter-weights within the political arena in reducing corruption. Thus, independent review projects was expanded to account for this issues.

Finally, in order to achieve a sustainable functioning, countries need at least three "enablers":

- Supportive legal framework
- Organized systems (to manage information)
- Technical competence of the staff

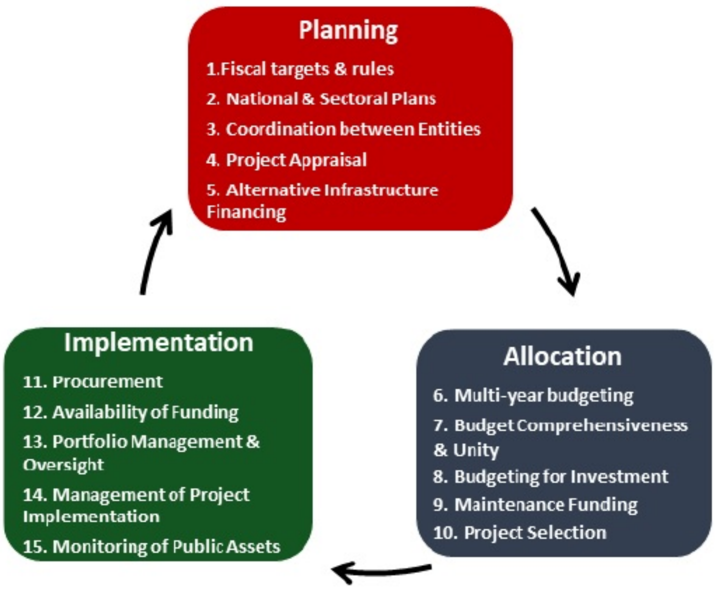
As these three issues are cross-cutting, they are assessed qualitatively and separately, with a focus on how they support the framework. All in all, the revised PIMA framework provides with accurate language all the necessary ingredients to enhance public infrastructure. More precisely, fiscal rules and principles are treated with more emphasis. In this manner, fiscal policy is important because it provides certainty to support public investment planning, budgeting, financing and execution. Therefore, instead of a single analysis, PPP are addressed in the context of several PIM institutions. In addition, some categories were merged into a single institution (budgeting comprehensiveness and unity) to facilitate the analysis. As regards the portfolio project management, several evaluation criteria were modified (e.g., the ability to shift money between approved projects) to facilitate the execution practice during projects. Lastly, the framework now includes public corporations as well as all potential financing sources.

FIGURE 1.2: PIMA Scores



Source: International Monetary Fund (2015)

FIGURE 1.3: Revised PIMA Framework



Source: International Monetary Fund (2018)

Public provision or Public-Private-Partnership?

Should governments continue to support conventional procurement? The provision of public infrastructure involves many challenges. First and foremost its funding, i.e., choosing the cheapest source (debt, tax or combination of both). The second one, involves stocks, quality and timing. As a matter of fact, given financial constraints (e.g., fiscal deficits), budget-time-schedules may be delayed or even postponed. Therefore, citizens may suffer from both low quality and lack of basic infrastructure.

Accordingly, should governments delegate infrastructure provision to private hands? In terms of participation, can PPP coexist simultaneously without reducing state's role? Which services should remain under governments "umbrella"? What have we learned from both types of provisions? As regards efficiency gaps: Can PPP alleviate fiscal deficits and boost infrastructure efficiency?

Focusing on traditional public investments and using comprehensive panel of countries, Cerra et al. (2017) find evidence that higher levels of public investments appear to be less important that one would expect, particularly for transportation (roads) and telecommunications (land lines). Yet, the net impact of infrastructure stock provision (i.e., electricity and transportation) is closely related to the funding sources: tax, debt or cut spendings. In fact, econometric results suggest that a 1% increase in the public capital-to-GDP ratio financed only with debt, may enhance road densities by 0.041% for the full sample whereas in Latin American countries the magnitude is considerable much higher (0.173%). Likewise, authors conduct the same exercise for electricity and the results hold and examine the financial (domestic) determinants of infrastructure expenditures. As one would expect, a 1% increase in the credit-to-GDP, foreign direct investment-to-GDP or trade-to-GDP ratio increases the share of domestic financing in total infrastructure by 0.40%, 0.48% and 0.34% respectively.

From a policymaking perspective caution must be taken as increasing public investment ratios to GDP do not guarantee infrastructure efficiency (Gurara et al., 2017). For example, during 2011-2015, the gaps exhibited between public investment and saving in low income and developing countries (LIDCs) widened at the expense of more debt financing projects. In other words, more fragile countries tend to rely more on debt rather than fiscal space (i.e., more discipline) to finance their projects. Moreover, fiscal vulnerabilities increased among commodity exporters countries along with rising interest rates and currency depreciations took place, ultimately augmented the burden over the debt services. Therefore, traditional public investments can be indeed insufficient. Conversely, let us consider PPP provision. A recurrent criticism that PPP receive is that they cost more per dollar of financing than government debt, the so-called PPP premium. For example, Yescombe (2011) argues that the cost of capital is between 200-300 basic points higher than the cost of public funds. Naturally, if governments do not have fiscal deficits, inflation nor exchange rate volatility, financing costs clearly will be lower. In this cases, public and not PPP should be considered. Additionally, the author points out that the spread over the lender's cost of funds is between 75-150 basic points (e.g., in the construction of highways). Therefore, public provision has a trade-off between lower cost of funds and higher private efficiency but more costly. Nonetheless, Klein (1997) states that arguments against private sector inefficiencies are far from being true, *"...because the cost of debt both to governments and to private firms is influenced by the perceived risk of default rather than an assessment of the quality of returns from the specific investment. We would lend to government even if we thought it would burn the money or fire it off into space, and we lend to it for both these purposes. p. 29"* (Kay, 1993). This means that at the end of the day, private market incentives will determine whether or not PPP is more appropriate than traditional provision.

Finally, considering the PIMA framework, the empirical evidence by IMF staff shows that more countries should voluntary embrace the program. In fact, it would be desirable to reduce efficiency gaps, particularly in African countries in which under-maintained stocks, budget execution failures (in terms of the planning and allocation) and hidden costs are still a major concern. Accordingly, addressing inefficiencies is also a win-win policy because countries may enhance citizens possibilities by offering productive opportunities to entrepreneurs.

For all the arguments mentioned above, both type of provisions (public and PPP) can perfectly coexist simultaneously. Under no circumstances governments may narrow the scope and proliferation of new PPPs nor cease to rely on traditional public investments. Certainly, for advanced economies —in which inflation, exchange rate volatility and political instability are lower— public investment may still have room for "large projects" such as bridges, highways, sewage systems, etc. Oppositely, low income economies in which check and balances, corruption and political instability are difficult to eradicate, PPP would bring more competition (by increasing infrastructure efficiency), alleviating fiscal needs and foremost, reducing the gap between citizen needs and state resources.

1.4 Empirical Evidence

During the past decades, there has been a widespread concern about infrastructure empirical effects over economic development. Indeed, its provision is multidimensional: not only stocks are important, but also quality matters as well (particularly in low income countries).

To this end, instead of testing econometrically which type of operator (public or private) is more appropriate to enhance economic development, we take advantage of different publicly available datasets to summarize current trends in infrastructure. At the same time, we use information about PPP projects performed in several countries to briefly describe the current situation in particular subsectors. Furthermore, we highlight the influence of infrastructure provision in both dimensions (stocks and quality service) over different indicators such as growth, institutions, inequality and labor productivity by means of bivariate linear regressions.

When considering public capital data for many countries, the natural choice is the capital stock database (International Monetary Fund, 2019*a*,*b*). However, measuring capital stocks is extremely difficult and estimates usually rely on the perpetual inventory method for which in each period, new investments are added to the existing stock. In order to accomplish such task, several and strong assumptions are made, especially for the depreciation rate.[21] In that line, the IMF follows two traditional works Kamps (2006) and Gupta et al. (2014) that make use of this technique to construct their database.[22]

Moreover, we enrich infrastructure data with traditional variables like Real GDP pc (Feenstra et al., 2015), gini index (Solt, 2019), labor productivity per-person employed and its growth rate from the Total Economy Database and central government debt (percent of GDP) from Mbaye et al. (2018). Additionally, we include infrastructure stocks such as electricity generation capacity,[23] fixed and mobile line subscriptions, paved roads (Castellacci and Natera, 2011) and also quality indicators such as rail quality, road quality, air quality, electricity quality, port quality and overall infrastructure quality from the World Economic Forum. We use the Global Competitiveness Index Historical Dataset. Unfortunately, the sample begins in 2007 and past information is limited for many countries. At last, we borrow all the political risk rating variables from the International Country Risk Guide. Table 1.1 contains a list of the countries and 1.2 variable definitions.

Descriptive Statistics and Correlations

Table 1.3 shows the summary statistics by income groups for different indicators. At first glance, it can been observed that productivity levels diverge among regions. Indeed, advanced

[21] Some limitations in regards to the use of such data are worth stressing. As Murphy and O'Reilly (2018) suggest, caution must be taken when using the capital stock data, particularly for private capital perpetual method estimations. Indeed, according to the authors an strong assumption was made by the IMF staff: ***"the fraction of investment that was private in the earliest year for which there is historical data was also the fraction for all preceding years"***. As a result, for some countries (e.g., Hong Kong) private capital stocks could have been overestimated. In this vein, the authors detected that almost 39% of the data points could be synthetic and this might indirectly impact nearly all the remaining observations.

[22] Both datasets: Public capital stock and PPIF (PPP) are available at `https://www.imf.org/external/np/fad/publicinvestment/` and `https://ppi.worldbank.org/en/ppidata` respectively.

[23] The International Energy Annual (IEA) is the Energy Information Administration's main source of energy statistics beginning in the year 1980. For more details see their website `http://www.eia.doe.gov/iea`.

economies have higher productivity levels per-person employed (85,290 usd) with respect to emerging & developing (31,996) and low income (7,958) ones. In that vein, the variation coefficient (second column) from the latter group confirms that those countries own more dispersion in productivity (0.61) in contrast to the emerging & developing (0.46) and advanced economies (0.22). This pattern (a priori) could indicate two major things: 1) infrastructure provision may suffer from inefficiencies, otherwise low income countries would have enhanced their productivity levels given their higher rates of public and private investment (12.7% and 85.7%) respectively. 2) hidden costs could be hindering infrastructure development, especially in underdeveloped regions.[24] In addition, income inequality measures as the Gini index is considerable much lower (0.30) in the advanced economies compared to the other regions (0.41). In that line, a possible explanation is the quality of institutions in each region. For instance, in the former group socioeconomic conditions, corruption and law & order (normalised scores) are significantly better (0.71, 0.69 and 0.87) while the performance in low income countries is considerable much lower (0.30, 0.37 and 0.50). Hence, this implies that societies with more inequality levels and at the same time, with a weaker quality of institutions (e.g., higher corruption levels), are less likely to take advantage of infrastructure provision (public or private) and enhance economic development.

Moreover, correlations are shown in Tables 1.4 and 1.5. On the one side, when GDP growth rate is negative (i.e., crisis takes place), capital stock growth rates (public and private) tend to decrease regardless the region considered (its coefficient is negative and significant). Likewise, higher levels of central governments' debt are negatively and significantly correlated with public capital stock growth rates. Surprisingly, in low income countries the relation is statistically insignificant but its negative sign holds. For the same token, a higher burden of public debt over GDP is also negative correlated with private capital stock growth rates whereas in low income countries the relation is positive but insignificant. On the other side, higher growth rates of labor productivity are positively correlated to capital growth. Hence, it seems that both types capital growth (public and private) can stimulate productivity or the other way around could be occurring; i.e., productivity growth may lead to more capital growth of the economy (reverse causality). Accordingly, how come low income countries are still unable to achieve higher standards of development if infrastructure investments increased? Earlier studies have explained that such differences could be the result of different human capital stocks, capital market imperfections or simply "political risk" (for a detailed discussion see Lucas, 1990).

[24] The International Monetary Fund (2015) report argues that efficiency increases with income per-capita. Yet, there are decreasing marginal returns to additional investments because once "universal cover" has been achieved, the scope for improvements is narrowed.

The institutional variables display interesting results. For example, government stability is positively correlated with public and private capital growth regardless the region considered. In plain words, popular governments with a strong legislative power are more likely to provide better economic conditions; thus, capital growth rates will rise. Yet, investment profile index enters with a positive sign only for the low income and emerging & developing regions but not for advanced economies. A possible explanation is the risk of contract expropriation in low income and emerging and developing economies. Simply put, the higher the reputation of a country (in terms of business contracts) the lower will be the likelihood of contract violation; thus, in well-functioning countries a marginal increase in their investment ranking will not produce a substantial growth in their capital stock (a sort of decreasing marginal returns on institutions). Likewise, corruption is negatively and significantly correlated with both types of capital growth. The explanation is straightforward, when corruption levels are high, governments' efficiency is reduced and also business functioning is affected due to bribes and dishonest behavior. Nonetheless, no plausible scientific explanation can be attributed by only hinging upon this simple relations because correlation does not imply causation.

Furthermore, when analysing infrastructure trends a natural question emerges: is digging a hole and filling it again a righteous policy? Can PPP compensate infrastructure shortages? What are the regions and the subsectors in which PPP concentrates more? In order to have a broader picture and be able to answer to those questions, we take a look at Figures 1.4, 1.5, 1.6, 1.7, 1.8, 1.9 1.10 and 1.11.

On the one hand, Figure 1.4 shows the growth rates of both public and private capital for different regions. Clearly, in low income (5.94%) countries private capital grew substantially more than public one until the Great Recession (2007-2010), period in which many banks went into bankruptcy and austerity took place (e.g., zero lower bound policies applied by the FED restricted investment flows). Likewise, the same pattern is observed in the rest of the groups. Notwithstanding, public capital growth rates are usually slack due to the large dimension of projects (e.g., bridges, highway networks), corruption and nepotism between different State levels and macroeconomic imbalances (e.g., fiscal deficits, inflation, public debt, among others). In that line, PPP seem an appealing alternative as they bring more efficiency by reducing the extent of such inefficiencies.

Following the previous argument, should infrastructure provision remain under the State "umbrella", PPP or both? In panels (a) and (b) of Figure 1.5 investment as a share of GDP is displayed. At first sight, it is clear that PPP investments account on average less than 1% of GDP while public investment is still above 4% of GDP regardless the income region. Naturally, those who cling on PPP provision would recommend for more policies to support and enhance the proliferation of these arrangements. Others more sceptics may argue that private funding cost (in terms of interest rates) are not as attractive as public ones. Given that both type of investments trends continue to be positive. Accordingly, using a simple empirical analysis we support the fact that both conventional public procurement and PPP can perfectly coexist.

Does the quantity of PPP projects matters? What are the subsectors mostly preferred by investors? In Figures 1.6 and 1.7 the total number of PPP projects and their shares by region are displayed. At first glance, we can observe that the majority of projects are targeted to Europe and Central Asia (2,340) followed by Latin American and Caribbean (2,077) and South Asia (1,289). In broader terms, the three regions accounted more than 77% of total PPP projects. As regards subsectors (Figures 1.8, 1.9 and 1.10), electricity attracted (3,438) projects followed by water and sewage (994) and roads (975). Overall, the three of them captured more than 73% of total PPP projects performed during the years 1990-2017. However, when considering the amount spent, transportation (roads) becomes important again. In fact, more than 1.2 billions of usd were targeted into electricity, roads and railways.

Finally, Figure 1.11 displays the list of countries with more quantity of projects. Naturally, one might regard that countries with more PPP projects would have been able to boost development more quickly. However, it is difficult to asses contrafactual scenarios hinging only on the quantity of infrastructure projects executed. Only China followed by India and Brazil seemed to have experienced a growth in the number of projects. Yet, without an econometric specification we cannot affirm that these countries had been able to achieved higher levels of development based only on their number of PPP investments.

All in all, using data on both public and PPP projects we have described the main trends on infrastructure around the world. Our analysis reveals the following stylized facts. First, increasing investments rates whether they are public or private do not necessarily mean more development. Second, the developmental financial side and the legal origin effects of PPI paramount. That is, given that institutional quality and productivity varies amongst countries, the returns of infrastructure investments will of course be heterogeneous. Third, infrastructure effects over economic development are multidimensional: stocks (e.g., new highway) and quality (better service) matter. Accordingly, in the next subsections, we will carry out a bivariate regressions keeping in mind that these do not account all the unobserved heterogeneity of other set of regressors and statistical inference could be compromise (i.e., spurious regression issue).[25] The goal of this exercise will be to shine some light on the quantity-quality infrastructure infrastructure trade-off over different indicators of development like Real GDP per capita, institutional quality, income inequality given by the Gini coefficient and labor productivity per worker employed. Finally, to account for the unobserved heterogeneity in PPI, a panel data approach will be employed. Particularly attention will be given to the developmental effects and the financial stability channel.

Infrastructure Stocks and Development

In order to analyze the influence of infrastructure stocks over development we rely on the strategy applied by previous research (Alesina and Perotti, 1996, Sanchez-Robles, 1998). Consequently, we focus on three key infrastructure sectors:

1. Telecommunications: number of telephone and mobile lines subscriptions.
2. Energy: electricity generation capacity (millions of KW).
3. Transportation: paved roads (percent of total roads).

When constructing a synthetic index, all variables must be in the same units of measure and standardized. In that vein, a natural choice would be to express them in units per-worker (Calderón et al., 2015). Yet, in our case, paved roads is already a proportion rate. Hence, before applying the principal component analysis, we re-express telecommunications and energy variables into the same unit.[26]

From the principal component analysis we can see that all three variables from equation 1.1 enter with approximately similar weights:

$$z_{it} = 0.2280 \cdot \left(\frac{Z_1}{AL}\right) + 0.3250 \cdot \left(\frac{Z_2}{AE}\right) + 0.4470 \cdot (Z_3) \tag{1.1}$$

where z is the synthetic infrastructure stock index, (Z_1/AL) is the proportion of fixed telephone lines over total lines (land + mobile lines), (Z_2/AE) is the proportion of electricity generation capacity over traditional energies (nuclear + hydroelectric) and (Z_3) is the proportion of paved roads over total roads.

[25] Another feasible strategy would be a time series approach, but it would have implied running 97 to 108 individual models (if data is available) in first differences and then check if the relationship is still statistically significant. Another important drawback of time series would cross-country comparisons. In other words, economic cycles tend to be associated to regional dependency; therefore, countries should be more or less similar.

[26] By applying this strategy, all variables are homogeneous before the standardization. Ideally, one could take the total length (in km) of roads or rails and then use all variables in per-worker terms and the outcome would be similar. Unfortunately, public data about roads or rails is limited and may display extreme variations. As a result, we rely on the CANA multiple imputation estimation of paved roads instead of using World Bank or Intentional Federation Road Statistics data.

At first sight, we can see that paved roads accounts 44% of the overall variance and is significantly correlated with our index. More precisely, its correlation is 0.688 while the correlation with main lines and electricity capacity is 0.473 and 0.674 respectively.

Likewise, we follow the same strategy when constructing the synthetic index of institutions. Yet, given the quantity of variables involved (twelve), we take the average of the components with more weight on the overall variance. Thus, the most important variables from equation 1.2 enter with the same proportion. Of course, their correlations with respect to the synthetic index are different. For example, the correlation of our institutional index and investment profile is 0.802 while the correlation with government stability and external conflict is 0.787 and 0.679 respectively.

$$i_{it} = 0.333 \cdot (I_1) + 0.333 \cdot (I_2) + 0.333 \cdot (I_3) \tag{1.2}$$

where i is the synthetic institution index, I_1 is the investment profile index, I_2 is the external conflict index and I_3 is the government stability index. In sum, all three variables account almost 70% percent of the overall variance.

Given the fact that updated information is extremely difficult to obtain, we restrict the scope of the sample to the years 1985 up to 2010. Overall, we have useful data for 97 countries from different income regions (low income, emerging & developing and advanced economies).

In Figures 1.12 and 1.13 our infrastructure stock indicator is measured against different development indicators. On the one hand, in panel (a) we first take into account the Real GDP per capita (expenditure side) to have first a visual inspection of the link between economic development and infrastructure provision. From the obtained relation, it is clear that larger infrastructure networks can boost living standards in most of the countries. Likewise, better quality of institutions (panel b) and labor productivity levels (d) are improved as infrastructure stocks grow. As for inequality, the relation is negative and strong meaning that countries with more infrastructure networks tend to have a better distribution of income.[27]

On the other hand, if we regard non-linearities (i.e., a quadratic relation) results are slightly better. Nonetheless, some caveats are worth mentioning. First, the best policy for one country must not necessary be the same for another one. Even if we would be able to control for heterogeneities among countries, a public policy of doubling infrastructure stocks does not assure reducing income inequality in the same proportion nor increasing productivity levels.

[27]In our analysis, each component of the stock index was equally weighted. As a result, the synthetic index is the average of the first three components. We also carried out the same exercise but using only the first component with the higher variance proportion (paved roads) and we obtained a better fit in both specifications. Yet, to our knowledge all components are important in explaining the stock of capital; thereby we rule out those results and rely on the former strategy.

Second, reverse causality cannot be disregarded. Nonetheless, disentangling such effects from a simple analysis is not possible without a proper econometric specification. Third, lower R-squares are the norm because infrastructure networks growth pace are mostly slack. Overall, our simple graphical analysis is line with the results obtained by Calderón and Servén (2010*b*).

Infrastructure Quality and Development

When accounting infrastructure quality and development relations, we make use of the overall quality index. Indeed, it is composed by five categories: rail quality, road quality, air quality, electricity quality and port quality. As a result, it ranges from 0 (minimum score) to 7 (maximum score).

The reason of using this composed index instead of the first principal components, is based on the correlations displayed by each category with respect to the index obtained from the principal component analysis. Indeed, quality of ports exhibits perfect correlation. What is more, the overall score is a weighted average of each category (i.e., it encompass a balanced judgement of quality). Therefore, ignoring components based on their variance proportion could seriously bias results.

For what concerns institutions, we apply the same strategy as before. We take the average of the components with more weight on the overall variance. Thus, the most relevant variables from equation 1.3 enter with the same proportion. Naturally, their correlations with respect to the synthetic index are different. For instance, the correlation of our institutional index and military in politics is 0.827 while the correlation with bureaucracy quality and government stability is 0.788 and 0.471 respectively.

$$qi_{it} = 0.333 \ \cdot (I_1) + 0.333 \ \cdot (I_2) + 0.333 \ \cdot (I_3) \tag{1.3}$$

where i is the synthetic institution index, I_1 is the military in politics index, I_2 is the bureaucracy quality index and I_3 is the government stability index. All three variables account 71% percent of the overall variance.

Moreover, given the fact that the Global Competitiveness Dataset database begins in the year 2007, we will not be able to make comparisons with respect to infrastructure stocks. Notwithstanding those limitations, we have useful data for 107 countries from different income regions (low income, emerging & developing and advanced economies).

In Figures 1.14 and 1.15 the infrastructure quality indicator is measured against different development indicators. As before, in panel (a) the Real GDP per capita (expenditure side) is taken into account to have first a visual description of development whilst in panels (b), (c) and (d) we focus on the quality of institutions, inequality and labor productivity. At first sight, all relations have the predicted sign and their R-squares (i.e., how close point estimates are to the fitted regression line) are considerably higher. More precisely, higher quality standards (e.g., better access to roads and maintenance levels) have an outstanding impact on economic development.

What is more, if we consider non-linearities (i.e., a quadratic relation) the adjustment fit improves for almost all indicators. Nonetheless, it seems that inequality results remain unchanged as in the linear case. A possible explanation lies on the nature of our exercise. In fact, we disregard reverse causality as well as other types of controls which clearly influence the a country income distribution. Therefore, two simple conclusion can be drawn.

First, infrastructure quality matters more than traditional stock investments. A clear example can be found in low income countries. For instance, in the Sub-Saharan region the situation is critical in terms of accessibility, under-maintenance and hidden costs because in those countries inequality and poverty are still at high levels (Briceño-Garmendia and Klytchnikova, 2006, Briceño-Garmendia et al., 2009). Second, policies aiming at enhancing the quality of institutions (e.g., in terms of bureaucracy quality) can have positive effects onto infrastructure quality provision and ultimately development. Third, it would seem that infrastructure quality has a higher impact over labor productivity (the major source of income per capita) rather than larger networks (stocks). Yet, no inferences can be made because there is no data for the years before 2007.

Overall, based on our bivariate analysis, we have found strong relations between infrastructure quality and development. Unfortunately, the overall quality index does not provide information about the type of operators (public or private). As a result, we cannot disregard that both type may coexist simultaneously. Finally, hardly any evidence about the existence of a trade-off between PPP and public provision has been brought. In other words, infrastructure is a public good with spillover effects onto economic development. Therefore, as a long as inefficiencies can be reduced, the type of operator may take a secondary place.

PPI, Financial Support, Legal Origin and Growth

As discussed earlier, existing literature (see, for example, Yehoue et al., 2006, Yescombe (2011), Queyranne et al., 2019) documents the determinants of PPI and its main channels (e.g., the macroeconomic financial stability channel). To the best of my knowledge, none those papers focused on the developmental financial side and the legal origin effects of new PPI at a cross-country level. To fill that gap, I explored that venue with time and regional fixed-effects interactions between an exogenous variation[28] in Multilateral Financial Support of PPI controlling for the institutional quality. Moreover, the empirical model assess the performance of two developing indicators: 1) Labor productivity and 2) Gini Index.

Accordingly, after checking the stationary properties of series, I include interactions between strictly exogenous regressors named: Multilateral Financial Support and Commercial French Legal Origin and the potential endogenous covariates. As regards the external instruments, I take from the existing literature the absolute latitude to the Equator, ethnic fractionalization index and whether or not they were former French colonies (see, La Porta et al. (1997), Acemoglu et al. (2001), La Porta et al. (2008), Dreher and Langlotz, 2020). In addition, I complement the above instruments with a weakly (past) predictor (cross-sectional average) of labor productivity. A similar approach has also been adopted in a recent paper (Gutiérrez-Romero, 2021) but using both time-invariant and varying past predictors of income inequality. This could be regarded as "first-stage" analysis for the relevance of selected historical values. Given that the panel employed in my study is unbalanced and sparse, I take those empirical insights to estimate an structural Limited-Information Maximum Likelihood (LIML) model.

Finally, I also control for cross-sectional dependence among unitus (see, for example, Pesaran (2021) for the standard test and the adjusted with weights Juodis and Reese, 2021) which is an important concern in panel data models. Nonetheless, if the DGP is too sparse and/or unbalanced, the p-values of the Pesaran (CD) and its weighted modified (CD_W) version test are never rejected. If so, to get an appropriate measure of the potential cross-sectional-dependency among units, one must sacrifice the number of countries and use a reduced (balanced) sample (36 in my case). This strategy is effective and reasonable given that PPI are mostly concentrated on developing economies. In that same line, the adoption of autocorrelated standard errors (HAC) with the Newey-West bandwidth adjustment and optimal lag selection and/or the Driscoll-Kraay approach for the standard errors are also valid strategies for this context. Both estimators are feasible because time span is not that small (T=26). In the case of lag selection, Stock et al. (2012) suggest that the optimal lag should be $0.75 \times T^{\frac{1}{3}}$ where T represents time. For the present empirical study, employing 3 lags comes at the cost of less countries but more efficient estimates in terms of arbitrary heterokedasticity and autocorrelation. As regards the use of other methodologies (e.g., Driscoll-Kray), there is no consensus on how large should be T. Moreover, the presence of endogenous covariates may lead to bias estimates. For those

[28] An interesting application of this approach was also applied by Dreher et al. (2021). Here this strategy is feasible because there is a considerably variability (mostly in low income income countries) in the institution quality w/wo financial assistance for PPI. That said, countries with financial support tend to have higher scores of corruption, law & order, bureaucracy and investment profile. In this way, the interactions capture the indirect effect while controlling for the potential endogeneity.

reasons, I use a two-way IV-FE LIML model HAC to ameliorate possible weak identifications while taking into account cross-sectional dependence among covariates.

Table 1.6 shows the developmental financial and legal effects of PPI for a reduced sample of countries using a LIML structural model. I depart from Yehoue et al. (2006) to check for the developmental effects of PPI on the macroeconomic stability channel controlling for institutions. More precisely, given that institutional quality shapes investors "animal spirits" and these are inversely related to financial security in terms of contract repudiation, I estimate very simple models to check the financial and legal effectiveness over growth using two indicators of developing. Throughout specifications, only institutional controls with strictly exogenous regressors are included. These differ on financial support and whether or not a legal French commercial code is implemented for new PPI. My results show that both developing indicators named: labor productivity and Gini index have the expected signs and are statistically significant. More importantly, all interactions are also positive and highly significant suggesting that PPI in countries with strong institutional indicators (e.g., corruption and bureaucracy scores) and French legal origins have a positive effect on economic growth. In other words, countries that receive financial support for their PPI projects have on average a higher GDP per capita with respect to those who did not engage on PPI programs other things being equal. Interestingly, this new evidence complements previous research on the effectiveness of legal institutions (see, for example, Pistor et al., 2000) and brings an additional new perspective on the developmental financial environment channel of new PPI.

1.5 Concluding Remarks

Infrastructure investments and the effects over economic development have always captured the attention of scholars. Nonetheless, its provision is challenging, not only stocks are important, but also quality matters as well. Additionally, given the size (in monetary terms) of some projects (e.g., a bridge or a new highway), policymakers must decide which source of funding is the most appropriate: debt, taxes or a combination of both. Along these lines, Public-Private-Partnerships (PPP) may be an effective alternative to the provision of public goods when governments suffer persistent fiscal deficits disorders and higher costs of contract repudiation. This paper ask whether public infrastructure continue to support economic development or else if PPP might assume such role. To answer that question, the paper draws on the large body of existing literature and to highlight both perspectives. Then, relying on publicly available datasets, updated trends on the link between infrastructure (public and private) and development are provided. Finally, in order to unpack the effects of infrastructure over development, bivariate and panel data regressions at a cross-country level are performed.

The extensive literature review from this paper confirms the presence of many channels operating simultaneously: macroeconomic stability (e.g., fiscal deficits, trade balance disorders, debt, etc) financial risk through institutional indicators (e.g., state regulations, control of corruption, a regulatory quality framework), among many others. New trends on infrastructure show that private capital growth rates are higher than public in both low Income, emerging and Developing (3.93%) compared to advanced economies (2%) on average. Therefore, if private investments are indeed much more productive than public ones, then, how come low income countries did not achieve higher living standards?

In order to answer the question from above this paper argues that PPP can alleviate infrastructure fiscal needs by mitigating its financial burden in the absence or partial presence of public provision. Therefore, bringing efficiency gains, for society as a whole: citizens, firms and governments. The preferred sectors for PPP investments are electricity, water and sewage (i.e., sanitization) and roads/highways which accounted more than 77% out of total projects during 1990-2017 period, a time where the total amount of investments encompassed more than 1.2 billions of USD. This suggests that transportation still requires large investments, mostly for maintenance. A growing number of performed projects is important although it does not imply more development (only China with more than 1,575 projects seemed to be exception given its leading role on global economy). Finally, this paper performs bivariate and panel data cross-country regressions to assess the link between infrastructure expenditures and development. Results for bivariate regressions between infrastructure and Real GDP per capita, labor productivity and income inequality (measured by the Gini index) indicate that efforts should be concentrated on improving quality rather than quantity (stocks) as these may boost even more living conditions. Unfortunately, cross-sectional models do not account all the unobserved heterogeneity nor the potential endogeneity amongst regressors. To account both issues, this paper considers panel data models for both public and private investments (PPI). Results show that “animal spirits” are inversely related to financial security in terms of contract repudiation for French origin laws. That is, countries that received Multilateral Financial Support (MFS) for new PPI projects have on average higher GDP pc and productivity levels offsetting inequality negative effects compared to those who did not engage on these programs other things being equal. Therefore, a good set of institutions provide the right incentives and may facilitate the interactions between the public and private sector so that both types of operators can coexist simultaneously.

In terms of policy implications, our analysis relies on the views expressed by Lin and Doemeland (2012) which suggest that a “growth lifting” strategy (by private hands) may be more appropriate to create new markets for manufacturing firms and establishments (supply side) but also more dynamism for regional labor markets in terms of new jobs and better salaries (demand side). However, to best of our knowledge, the evidence from this paper suggest that PPI can also provide an alternative to traditional public procurement. We hasten to point whether or not governments under specific conditions should participate on PPP experiences as different channels could be at work. Although we retain that doubling current investments will not necessarily lead to instantaneous improvements as the best policy for one country may not necessary be the same for another one. All in all, infrastructure expenditures are a win-win policy because these type of investments improve the quality of living standard among countries, and foremost, settle the path for productivity growth (one of the most important sources of economic development) allowing to take advantage of productive opportunities to unskilled workers and entrepreneurs while improving income distribution as countries develop.

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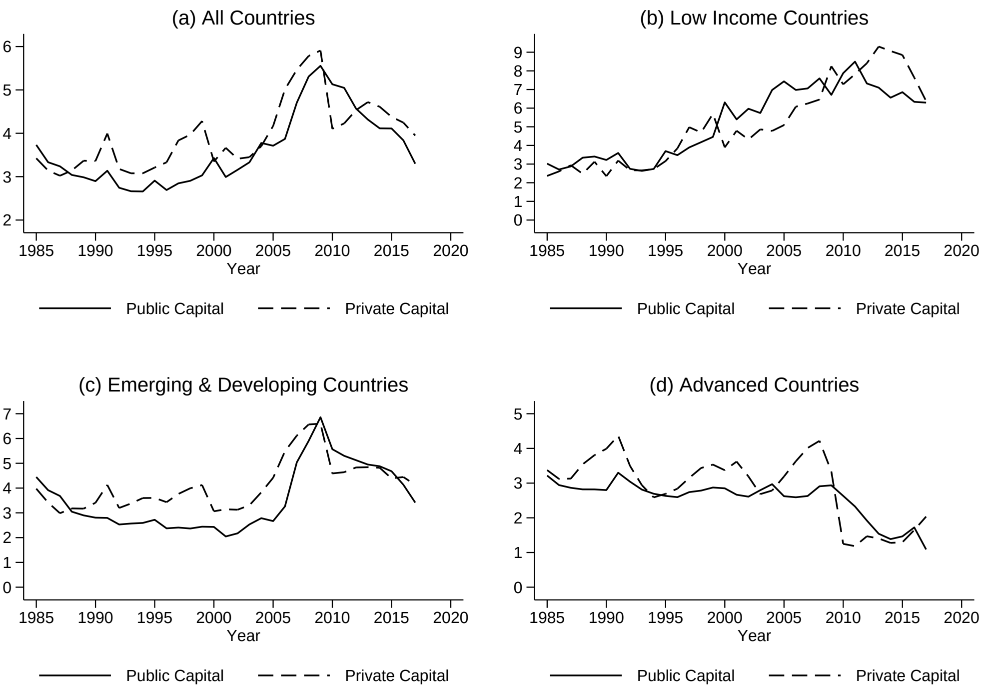
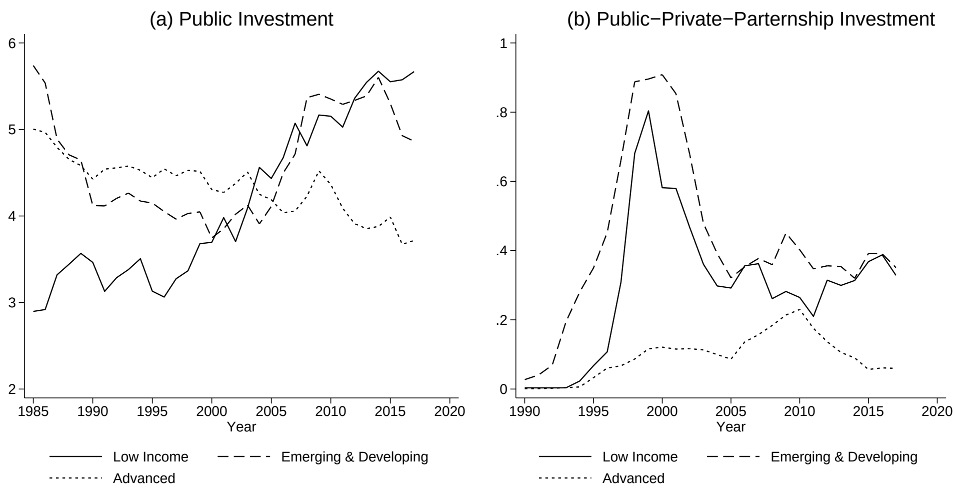
Figures

FIGURE 1.4: Capital stock growth rates by income region: 1985-2017



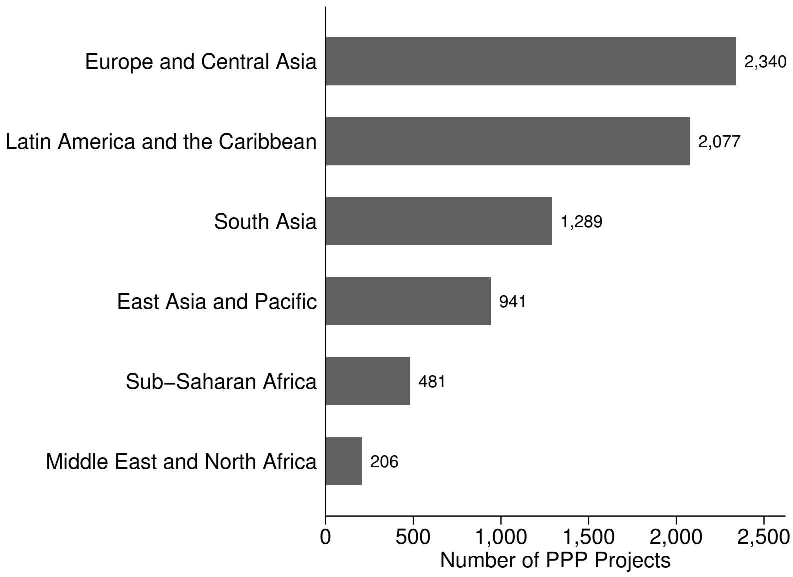
Note: both types of capitals are measured as growth rates (percentage change) with respect to their previous year. Source: author own calculations based on the Capital Stock Dataset (IMF).

FIGURE 1.5: Infrastructure investments by income region: 1985-2017



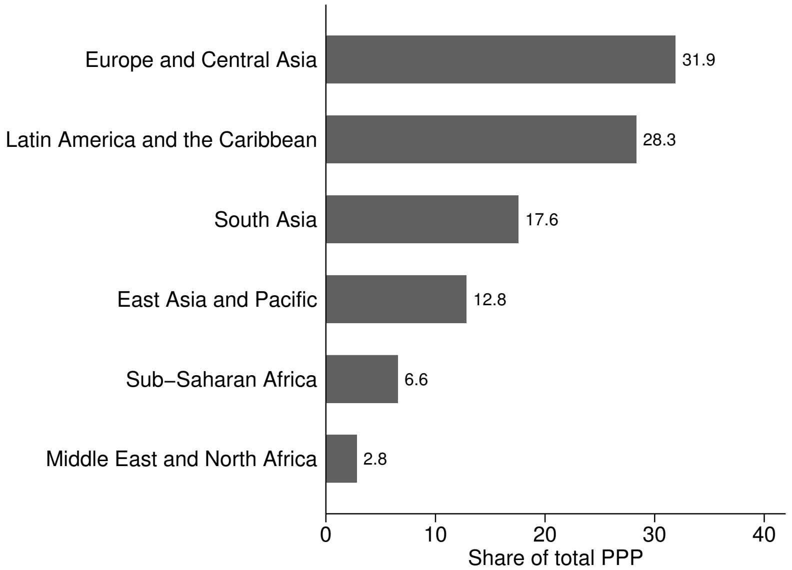
Note: both types of investments are calculated as share of GDP. Source: author own calculations based on the Capital Stock Dataset (IMF).

FIGURE 1.6: Total number of PPP projects by regions: 1990-2017



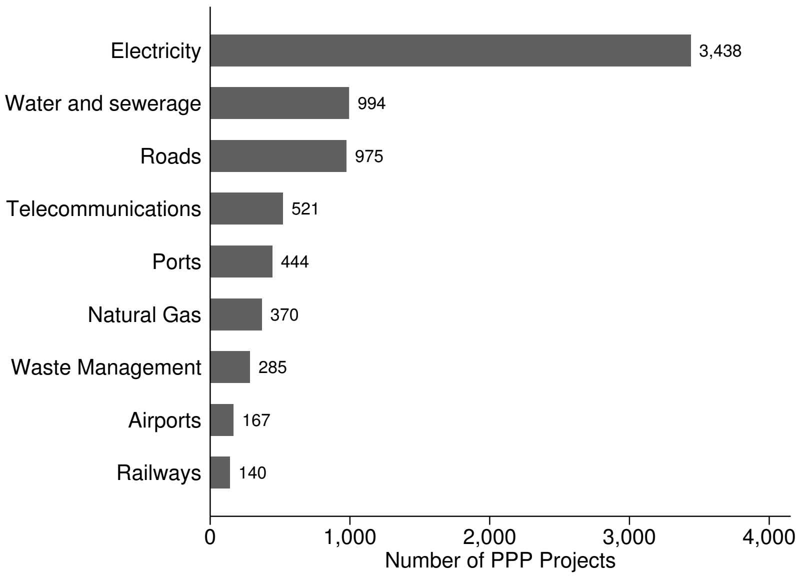
Source: author own calculations based on PPIF (World Bank) dataset.

FIGURE 1.7: Share of PPP to total projects by regions: 1990-2017



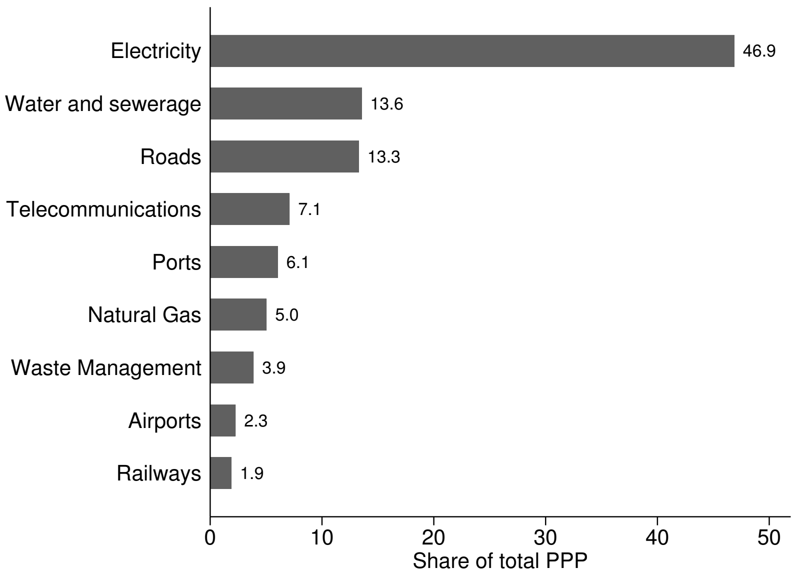
Source: author own calculations based on PPIF (World Bank) dataset.

FIGURE 1.8: Subsectors ranked by number of projects: 1990-2017



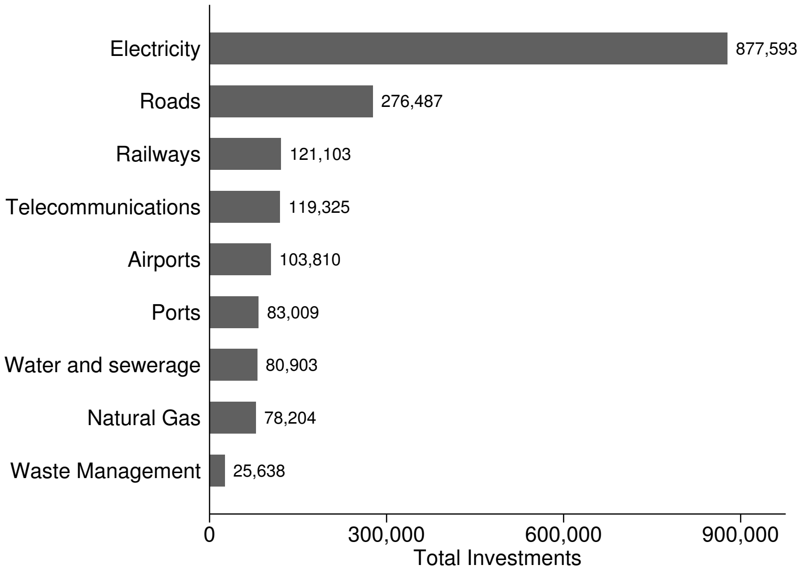
Source: author own calculations based on PPIF (World Bank) dataset. To reduce the extent of subsectors, several categories were merged: Water and sewerage includes treatment plant and water utility. Waste Management: takes into account treatment/disposal, integrated solid waste management and collection & transport.

FIGURE 1.9: Share of PPP by sub-sectors: 1990-2017



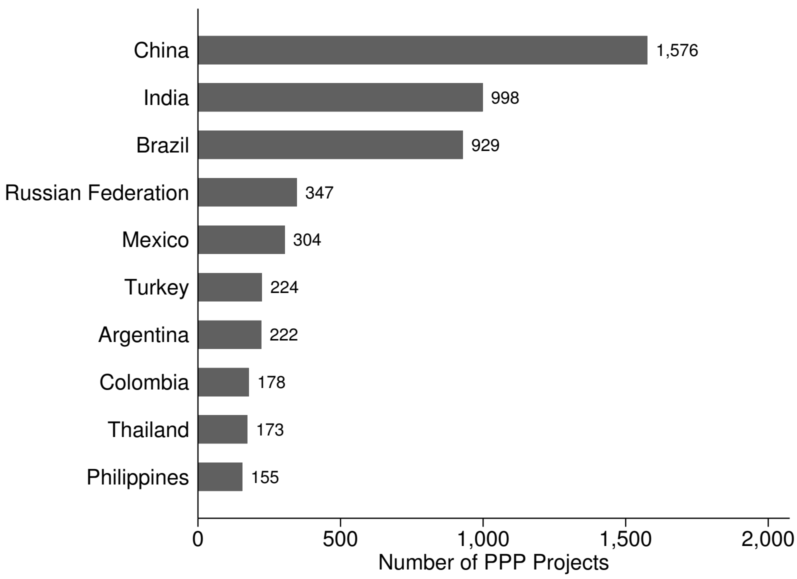
Source: author own calculations based on PPIF (World Bank) dataset. To reduce the extent of subsectors, several categories were merged: Water and sewerage includes treatment plant and water utility. Waste Management: takes into account treatment/disposal, integrated solid waste management and collection & transport.

Figure 1.10: Sub-sectors ranked by amount of investments: 1990-2017



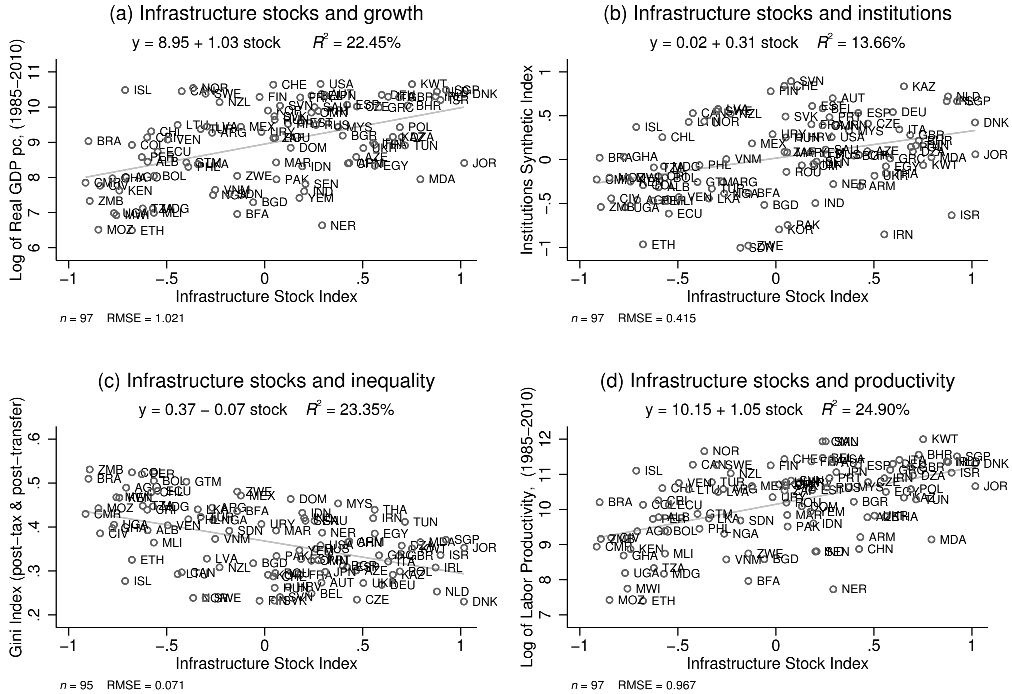
Source: author own calculations based on PPIF (World Bank) dataset. To reduce the extent of subsectors, several categories were merged: Water and sewerage includes treatment plant and water utility. Waste Management: takes into account treatment/disposal, integrated solid waste management and collection & transport. Data is measured on USD$ millions.

Figure 1.11: Top 10 countries by number of projects: 1990-2017



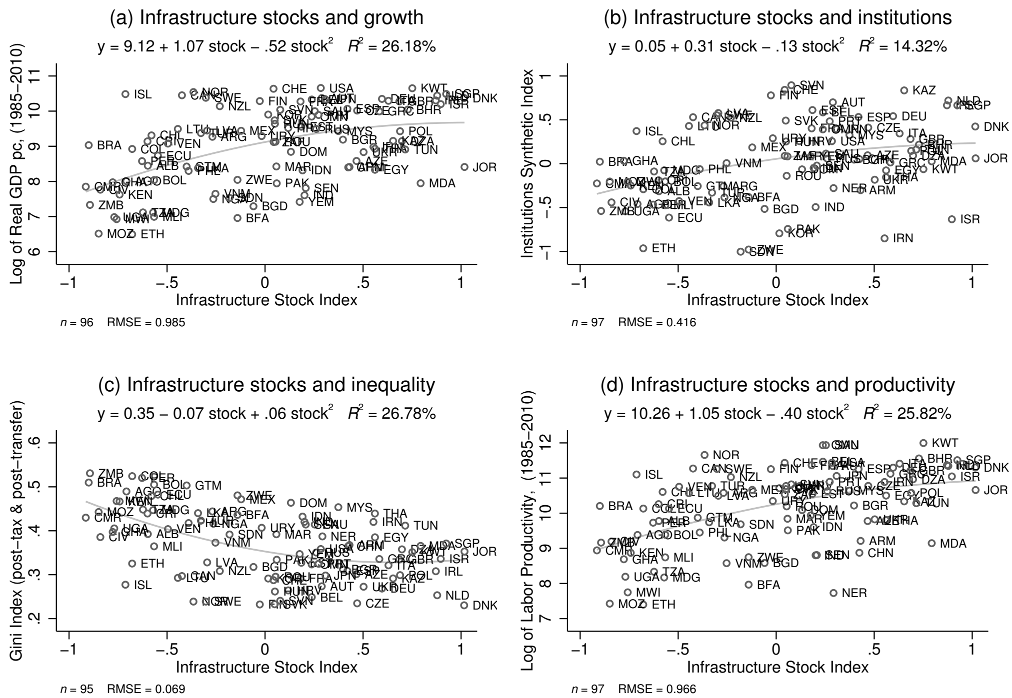
Source: author own calculations based on PPIF (World Bank) dataset.

FIGURE 1.12: Infrastructure stocks and development: Linear Fit



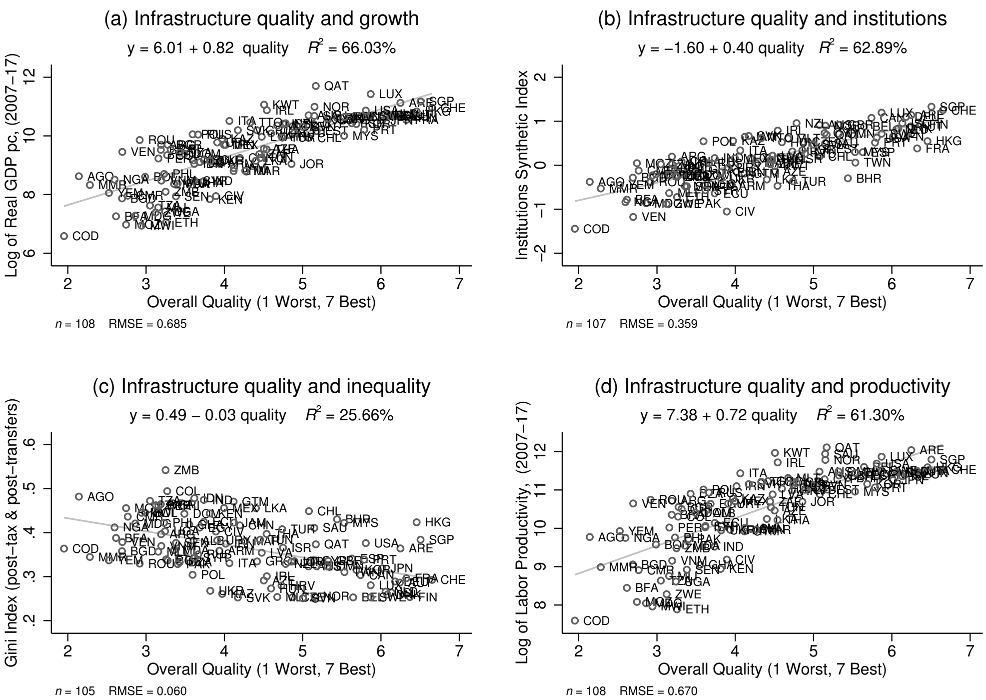
Note: countries with extreme observations were excluded from the analysis. Source: author own calculations.

FIGURE 1.13: Infrastructure stocks and development: Quadratic Fit



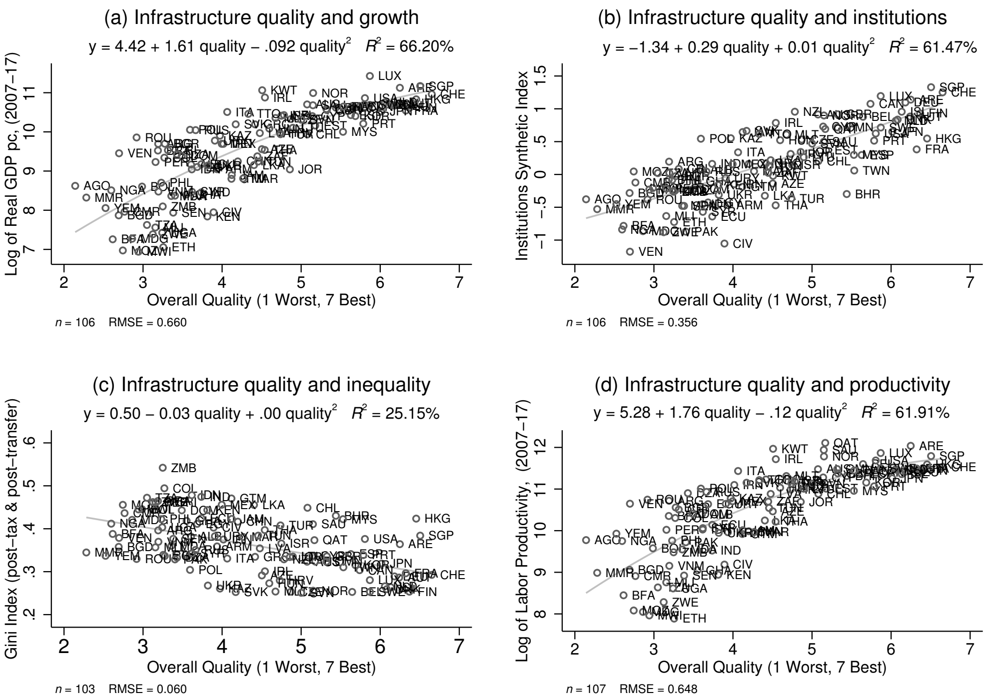
Note: countries with extreme observations were excluded from the analysis. Source: author own calculations.

FIGURE 1.14: Infrastructure quality and development: Linear Fit



Note: countries with extreme observations were excluded from the analysis. Source: author own calculations.

FIGURE 1.15: Infrastructure quality and development: Quadratic Fit



Note: countries with extreme observations were excluded from the analysis. Source: author own calculations.

Tables

Table 1.1: List of countries

World Economic Outlook Classification

Low Income Countries		Emerging & Developing Countries		Advanced Countries	
Bangladesh	Mozambique	Albania	Jordan	Austria	Latvia
Burkina Faso	Myanmar	Algeria	Kazakhstan	Belgium	Lithuania
Cameroon	Niger	Angola	Kuwait	Canada	Luxembourg
Congo, Dem. Rep.	Nigeria	Argentina	Malaysia	Cyprus	Malta
Cote d'Ivoire	Senegal	Armenia	Mexico	Czech Republic	Netherlands
Ethiopia	Sudan	Azerbaijan	Morocco	Denmark	New Zealand
Ghana	Tanzania	Bahrain	Oman	Estonia	Norway
Kenya	Uganda	Belarus	Pakistan	Finland	Portugal
Madagascar	Vietnam	Bolivia	Peru	France	Singapore
Malawi	Yemen, Rep.	Brazil	Philippines	Germany	Slovak Republic
Mali	Zambia	Bulgaria	Poland	Greece	Slovenia
Moldova	Zimbabwe	Chile	Romania	Hong Kong	Spain
		China	Russian Federation	Iceland	Sweden
		Colombia	Saudi Arabia	Ireland	Switzerland
		Costa Rica	South Africa	Israel	Taiwan
		Croatia	Sri Lanka	Italy	United Kingdom
		Dominican Republic	Syrian Arab Republic	Japan	United States
		Ecuador	Thailand	Korea, Rep.	
		Egypt, Arab Rep.	Tunisia		
		Guatemala	Turkey		
		Hungary	Ukraine		
		India	United Arab Emirates		
		Indonesia	Uruguay		
		Iran, Islamic Rep.	Venezuela, RB		
		Iraq			

Table 1.2: Variables, Definitions and Sources

Variable	Definition	Source
GDP	Gross Domestic Product (2011 billions USD constant)	Capital Stock Dataset
GDP pc	Gross Domestic Product per-capita (2011 USD thousands)	Author
GDP gr	Growth Rate of GDP (percent)	Author
Crisis	Dummy equals 1 if GDP gr is negative	Author
Gini Index	Gini (post-tax, post-transfer)	SWIID 8.1
Labor Productivity	Labor Productivity per-person (2011 USD thousands)	TED
Labor Productivity gr	Labor Productivity per-person (percent)	TED
RGDPE pc	Real GDP per-capita exp.side: RGDPE/pop (2011 USD thousands)	Own based on PWT 9.1
Public Capital Stock	General Government Capital stock (2011 billions USD constant)	Capital Stock Dataset
Public Capital gr	Growth Rate of General Government Capital stock (percent)	Author
Public Capital pc	General Government Capital Stock per-capita (2011 USD thousands)	Author
Public Investment	General Government Investment (2011 billions USD constant)	Capital Stock Dataset
Public Investment gr	Growth Rate of General Government Investment (percent)	Author
PPP Investment	Public-Private-Parternship Investment (2011 billions USD constant)	Capital Stock Dataset
PPP gr	Growth Rate of PPP (percent)	Own
Private Capital Stock	Private Capital Stock (2011 billions USD constant)	Capital Stock Dataset
Private Capital gr	Growth Rate Private Capital Ctock (percent)	Own
Private Capital Stock pc	Private Capital Stock per-capita (2011 USD thousands)	Author
Public Debt (%GDP)	Central Government Debt (percent of GDP)	Global Debt Database
Socioeconomic Conditions	Socioeconomic pressures (index)	ICRG
Investment Profile	Investment risk (index)	ICRG
Internal Conflict	Political violence (index)	ICRG
External Conflict	Incumbent attack (index)	ICRG
Corruption	Corruption (index)	ICRG
Military Politics	Military regime risk (index)	ICRG
Religious Tensions	Religious tensions risk (index)	ICRG
Law & Order	Legal system and judicial quality (index)	ICRG
Ethnic Tension	Racial measure (index)	ICRG
Democratic Accountability	Quality of government (index)	ICRG
Bureaucracy Quality	Quality of government policies (index)	ICRG
Electricity Share	Electricity generation capacity / (Nuclear + Hydroelectric)	Author based on EIA
Land Lines Share	Fixed Telephone Subscriptions / (Fixed + Mobile subscriptions)	Author based on WDI
Paved Roads Share	Roads, paved (% of total roads)	CANA
Infrastructure Quality	Rail, Road, Air, Electricity, Port and Overall Quality	WEF

Table 1.3: Summary Statistics: 1985-2017

	Low Income Countries				Emerging & Developing Countries			
	Mean	CV	Min	Max	Mean	CV	Min	Max
GDP pc.	2,528	0.47	544.30	5,570	11,201	0.46	1,914	26,361
GDP gr.	2.49	1.47	-17.30	18.30	3.07	1.43	-14.80	33.00
Public Capital pc.	582.10	0.43	199	1,299	593.50	0.50	32.80	1,828
Public Capital gr.	5.72	1.00	-2.70	37.20	3.59	0.98	-2.58	56.80
Public Investment gr.	12.70	3.82	-79.50	550.10	9.12	3.70	-71.90	463.90
Private Capital pc.	1,162	0.50	323.60	3,095	1,540	0.38	293.40	4,377
Private Capital gr.	5.94	1.02	-4.72	50.00	3.93	0.87	-3.32	17.70
PPP Investment gr.	85.70	7.74	-100.00	9,875	166.90	12.00	-100.00	36,606.20
Labor Productivity	7,958	0.61	1,670	26,114	31,996	0.46	4,617	76,136
Labor Productivity gr.	2.30	1.66	-20.00	18.30	2.51	1.82	-13.70	32.90
Gini Index	0.41	0.12	0.32	0.55	0.41	0.19	0.24	0.60
Public Debt (% GDP)	55.40	0.64	7.28	261	42.70	0.57	3.67	179.80
Government Stability	0.69	0.21	0.27	0.92	0.64	0.24	0.17	0.95
Socioeconomic Conditions	0.30	0.43	0.05	0.71	0.46	0.33	0	0.90
Investment Profile	0.60	0.21	0.17	0.83	0.64	0.24	0.20	0.98
Internal Conflict	0.70	0.19	0.25	1	0.73	0.20	0.04	1
External Conflict	0.84	0.13	0.51	1	0.83	0.13	0.46	1
Corruption	0.37	0.36	0	0.67	0.41	0.32	0.17	0.83
Military in Politics	0.49	0.39	0	0.83	0.62	0.40	0	1
Religious Tensions	0.69	0.35	0.08	1	0.74	0.34	0	1
Law & Order	0.50	0.31	0.08	0.83	0.55	0.31	0.17	1
Ethnic Tensions	0.55	0.32	0.17	1	0.66	0.32	0.17	1
Democratic Accountability	0.55	0.36	0	0.92	0.67	0.34	0	1
Bureaucracy Quality	0.36	0.50	0	0.75	0.50	0.34	0	1
Observations	297				709			

	Advanced Countries				All countries			
	mean	cv	min	max	mean	cv	min	max
GDP pc.	34,494	0.24	10,590	67,456	14,472	0.87	544.3	67,456
GDP gr.	1.50	1.99	-9.01	24.60	2.58	1.54	-17.30	33.00
Public Capital pc.	627.60	0.24	303.20	1,107	598.60	0.43	32.80	1,828
Public Capital gr.	1.88	1.01	-1.59	8.90	3.69	1.11	-2.70	56.80
Public Investment gr.	2.10	6.56	-39.60	93.20	8.37	4.17	-79.50	550.10
Private Capital pc.	2,346	0.15	1,446	3,160	1,636	0.41	293	4,377
Private Capital gr.	2.00	0.92	-3.86	14.10	3.95	1.05	-4.72	50.00
PPP Investment gr.	34.40	5.96	-100.00	2,077	118.40	12.80	-100.00	36,606.20
Labor Productivity	85,290	0.22	31,508	143,712	38,521	0.79	1,670	143,712
Labor Productivity gr.	1.15	1.71	-6.01	9.08	2.16	1.85	-20.00	32.90
Gini Index	0.30	0.12	0.24	0.37	0.38	0.21	0.24	0.60
Public Debt (% GDP)	63.30	0.54	8.54	187.30	50.20	0.61	3.67	261.00
Government Stability	0.63	0.22	0.30	0.92	0.65	0.23	0.17	0.95
Socioeconomic Conditions	0.71	0.19	0.33	1	0.48	0.42	0	1
Investment Profile	0.84	0.19	0.42	1	0.68	0.26	0.17	1
Internal Conflict	0.86	0.11	0.54	1	0.75	0.20	0.04	1
External Conflict	0.89	0.11	0.54	1	0.85	0.13	0.46	1
Corruption	0.69	0.26	0.33	1	0.46	0.41	0	1
Military in Politics	0.95	0.08	0.69	1	0.67	0.40	0	1
Religious Tensions	0.89	0.13	0.67	1	0.76	0.31	0	1
Law & Order	0.87	0.14	0.50	1	0.61	0.35	0.08	1
Ethnic Tensions	0.73	0.24	0.33	1	0.65	0.32	0.17	1
Democratic Accountability	0.96	0.07	0.67	1	0.71	0.34	0	1
Bureaucracy Quality	0.88	0.16	0.50	1	0.55	0.45	0	1
Observations	293				1299			

Note: Institutional variables are measured in different scales. Therefore, they were standardized in order to make them comparable. Source: author own calculations.

Table 1.4: Public capital pairwise correlations: 1985-2017

	Low Income Countries		Emerging & Developing Countries		Advanced Countries		All Countries	
	P.Corr	P-Value	P.Corr	P-Value	P.Corr	P-Value	P.Corr	P-Value
Public Capital gr.	1		1		1		1	
Private Investment gr.	−0.019	0.711	−0.021	0.541	−0.023	0.683	−0.014	0.585
GDP gr.	0.237	0.000	0.057	0.025	0.124	0.000	0.111	0.000
Gini Index (post-tax)	−0.205	0.000	0.001	0.974	0.167	0.000	0.099	0.000
Labor Prod. gr.	0.238	0.000	0.070	0.005	0.176	0.000	0.119	0.000
Public Debt (% GDP)	−0.016	0.695	−0.171	0.000	−0.334	0.000	−0.115	0.000
Government Stab.	0.249	0.000	0.089	0.001	0.085	0.005	0.110	0.000
Socioeconomic Cond.	−0.055	0.127	0.168	0.000	−0.204	0.000	−0.124	0.000
Investment Profile	0.185	0.000	0.149	0.000	−0.124	0.000	−0.016	0.347
Internal Conflict	0.116	0.001	0.041	0.113	0.076	0.013	−0.050	0.004
External Conflict	0.071	0.047	−0.035	0.173	−0.105	0.001	−0.069	0.000
Corruption	−0.141	0.000	−0.098	0.000	−0.288	0.000	−0.230	0.000
Military in Politics	−0.086	0.016	−0.054	0.036	−0.333	0.000	−0.209	0.000
Religious Tensions	0.050	0.166	−0.038	0.141	0.012	0.683	−0.071	0.000
Law & Order	0.015	0.668	0.019	0.457	−0.290	0.000	−0.152	0.000
Ethnic Tensions	0.145	0.145	−0.032	0.219	0.023	0.461	−0.064	0.000
Democractic Account.	−0.060	0.094	−0.101	0.000	−0.399	0.000	−0.222	0.000
Bureaucracy Quality	−0.184	0.000	0.049	0.056	−0.431	0.000	−0.227	0.000
Crisis	−0.258	0.000	−0.051	0.042	0.020	0.494	−0.083	0.000

Source: author own calculations.

Table 1.5: Private capital pairwise correlations: 1985-2017

	Low Income Contries		Emerging & Development Countries		Advanced Countries		All countries	
	P.Corr	P-Value	P.Corr	P-Value	P.Corr	P-Value	P.Corr	P-Value
Private Capital gr.	1		1		1		1	
Public Investment gr.	−0.045	0.204	−0.008	0.756	0.128	0.000	−0.014	0.407
GDP gr.	0.208	0.000	0.084	0.001	0.199	0.000	0.130	0.000
Gini Index (post-tax)	−0.081	0.051	0.024	0.385	0.139	0.000	0.125	0.000
Labor Prod. gr.	0.217	0.000	0.110	0.000	0.151	0.000	0.133	0.000
Public Debt (% GDP)	0.053	0.186	−0.101	0.000	−0.334	0.000	−0.062	0.001
Government Stab.	0.257	0.000	0.152	0.000	0.112	0.000	0.151	0.000
Socioeconomic Cond.	−0.073	0.041	0.243	0.000	−0.028	0.355	−0.080	0.000
Investment Profile	0.174	0.000	0.251	0.000	−0.069	0.023	0.026	0.129
Internal Conflict	0.053	0.140	0.134	0.000	0.120	0.000	−0.023	0.186
External Conflict	0.007	0.855	0.064	0.012	−0.146	0.000	−0.054	0.002
Corruption	−0.089	0.013	−0.018	0.490	−0.165	0.000	−0.183	0.000
Military in Politics	−0.130	0.000	−0.001	0.963	−0.331	0.000	−0.200	0.000
Religious Tensions	−0.073	0.041	−0.105	0.000	0.051	0.094	−0.136	0.000
Law & Order	0.147	0.000	0.220	0.000	−0.188	0.000	−0.045	0.009
Ethnic Tensions	0.084	0.020	0.076	0.003	0.031	0.309	−0.021	0.231
Democractic Account.	−0.036	0.321	−0.032	0.218	−0.388	0.000	−0.192	0.000
Bureaucracy Quality	−0.069	0.054	0.129	0.000	−0.272	0.000	−0.165	0.000
Crisis	−0.256	0.000	−0.047	0.061	−0.041	0.159	−0.095	0.000

Source: author own calculations.

TABLE 1.6: Public-Private-Investments, Financial Support, Legal Origin and Growth

LIML Estimates: 1990-2015

	Dependent variable is log GDP per capita (expenditure side)									
(log of) Labor Productivity	0.478^{***}	0.476^{***}	0.478^{***}	0.481^{***}	0.479^{***}	0.496^{***}	0.491^{***}	0.496^{***}	0.498^{***}	0.496^{***}
	[0.069]	[0.069]	[0.069]	[0.069]	[0.069]	[0.069]	[0.069]	[0.069]	[0.069]	[0.069]
(log of) Gini Index post-tax	-0.653^{*}	-0.640^{*}	-0.577	-0.589	-0.613^{*}	-0.540	-0.559	-0.471	-0.488	-0.511
	[0.366]	[0.369]	[0.359]	[0.363]	[0.363]	[0.350]	[0.353]	[0.342]	[0.346]	[0.346]
(log of) PPI Investments × MFS	0.061^{***}	0.050^{***}	0.060^{***}	0.057^{***}	0.057^{***}					
	[0.016]	[0.017]	[0.017]	[0.017]	[0.017]					
(log of) PPI Investments × French Origin	0.005	0.005	0.005	0.006	0.005	0.013^{**}	0.011^{*}	0.013^{**}	0.013^{**}	0.012^{**}
	[0.007]	[0.007]	[0.006]	[0.007]	[0.007]	[0.006]	[0.006]	[0.006]	[0.006]	[0.006]
Corruption × MFS	0.265^{***}					0.242^{***}				
	[0.076]					[0.073]				
Bureaucracy quality × MFS		0.222^{***}					0.240^{***}			
		[0.062]					[0.061]			
Law & Order × MFS			0.185^{***}					0.164^{***}		
			[0.062]					[0.062]		
Investment profile × MFS				0.139^{***}					0.130^{***}	
				[0.050]					[0.050]	
Institutional Quality × MFS					0.210^{***}					0.202^{***}
					[0.065]					[0.063]
Hansen J test (p-value)	(0.724)	(0.622)	(0.708)	(0.709)	(0.685)	(0.874)	(0.739)	(0.862)	(0.856)	(0.832)
Ramsey-Pesaran-Taylor test (p-value)	(0.630)	(0.606)	(0.537)	(0.554)	(0.581)	(0.455)	(0.466)	(0.388)	(0.400)	(0.425)
Sanderson-Windmeijer F-statistic$^{\phi}$	35.310	35.320	35.560	35.560	35.500	35.320	35.380	35.570	35.600	35.530
Sanderson-Windmeijer F-statistic$^{\Psi}$	43.270	44.060	44.330	44.380	44.180	44.260	44.940	45.210	45.320	45.110
Number of observations	637	637	637	637	637	637	637	637	637	637
Number of countries	36	36	36	36	36	36	36	36	36	36
CSD test (p-value)	(0.103)	(0.189)	(0.146)	(0.179)	(0.154)	(0.097)	(0.130)	(0.135)	(0.154)	(0.121)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Regional FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Financial support controls	Y	Y	Y	Y	Y	N	N	N	N	N
Legal controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Institutional controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes:
a. Institutional quality (normalised) is defined as the average score of corruption, law & order bureaucracy and investment profile. MFS is dummy equal 1 for PPI projects with financial assistance. Legal origin is a dummy variable equal to 1 for the French Commercial Code and 0 in cc.
b. ϕ corresponds to the labor productivity endogenous regressor while Ψ for the gini index. In the case of two endogenous regressors the Angrist-Pischke is replaced by Sanderson and Windmeijer statistic (S-W). The individual S-W (conditional) F-statistics provide further information about which endogenous explanatory variables are poorly predicted by the selected instruments. Results show that p-values from these robust test statistics reject the null hypothesis of underidentification at the 1% level.
HAC standard errors in brackets at country level small sample adjustment. The number of optimal lags for the bandwidth is 3. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: author own calculations.

Chapter 2

Better safe than sorry?

Infrastructure, State Incentives and Innovation across U.S states

2.1 Introduction

Regional development as well as the identification of the proper policies have always captured the attention of scholars. In this vein, infrastructure investments —whether these are performed by public or private hands— may be regarded as "boosters" for regional and local economies in terms of new establishments, additional jobs and foremost the enhancement of distressed places. Although the scope of infrastructure has evolved over time, labor market response at an industry level has not been fully explored.[1]

At first glance, the transmission mechanism by which these expenditures affect regional employment constitute a first-order "direct effect" regardless the industry under consideration. For instance, during the Great Recession in the U.S, high-tech industries like computer and electronic manufacturing experienced a fell of 6.2 percent jobs in Colorado with an overall fall of 3.6 percent jobs in total private employment whilst in the telecommunication sector, the converse occurred: private employment grew 4.6 and 0.7 percent respectively.

In response to such disparities in regional performance, policymakers may consider that well-targeted stimulus spending may facilitate recovery for the areas most in need (e.g., the American Recovery and Reinvestment Act better known as "ARRA").[2] Although, the interaction of several and possibly opposed effects within each region (e.g., different tax incentives,

[1]For example, a recent work of Hooper et al. (2018) explores the relationship between transportation spending (i.e., highways) and income inequality across U.S states. Results using top income shares and the Gini index, show that the construction sector plays an important role in reducing inequality. Hence, infrastructure investments within this industry allow workers to switch to better remunerated jobs.

[2]The empirical results considering the ARRA event study cannot reject the "crowding out" hypothesis (Dupor, 2017). In fact, after controlling for population density, hardly any positive or negative correlation exists among U.S states. More precisely, it seems that highway infrastructure spending may have been very similar with or without the implementation of such program.

innovation activities performed by firms, quality of institutions, etc) might affect the final outcome; ultimately, whether or not is there any effect over employment remains an empirical question.

Studies show that the high-tech sector has the largest multiplier effect (5.9) in terms of job-creation rates whereas the effect on manufacturing industries is positive but far modest (2.6). Expressed differently, for each additional job in the former industry, 5.9 jobs are created in the non-tradable sector. Indeed, as the number of workers and equilibrium wages rise, so does the (local) demand of goods and services (e.g., hair-cuts, medical services, etc). In particular, the higher the level of human capital (skill-jobs), the larger will be these effects, especially for high-technology jobs. Clearly, the presence of direct "local" or "diffuse" multiplier effects hinges upon the location of where these additional goods and services are being spent (see, for example, Moretti, 2010 and Moretti and Thulin, 2013).[3]

For what concerns the role of public policies, like industry subsidies or tax-cuts, so far results have not been traduced into higher job-creation rates nor more innovative activities from firms (one of the major source business dynamism).[4] As a matter of fact, several stylized facts observed from the data suggest that the U.S economy is facing a slowdown.

On the one hand, some argue that the economy is running out of ideas despite outstanding efforts in a context where productivity rates are in continuing fall (Bloom et al., 2017). In that vein, the pace of fruitful innovations is reaching to an end and above all, many inventions that took place during the Second Industrial Revolution (e.g., transportation, communication, etc) could have happened only once (Gordon, 2012).

On the other hand, the rise of "superstar firms" along with industry concentration and stagnation of technology diffusion measured by the quantity of patent and citations (see, for example, Autor et al. (2017, 2020) and Akcigit and Ates, 2019*b*), could also be responsible for the decreasing job creation rates in the U.S economy. For instance, one firm or a small group of it—which are more productive— can take advantage of their position due to the access to new competitive platforms or simply by using high-quality goods with lower marginal costs like

[3]According to Bartik and Sotherland (2019), such estimates only show a part of the agglomeration economies and congestion effects as they are calculated at the sample mean shares. In fact, the problem arises because Moretti uses the actual change in manufacturing as a projected instrument of total employment while at the same time, the variables of the model do not take into account the shock in terms of total employment. Hence, the multipliers reported in the second stage —depending upon the initial sector share— will tend to display higher values and vary across the sample. Consequently, state and local policymakers decisions could be biased towards the implementation of economic development programs to attract only high-tech firms.

[4]For instance, Trogen (1999) showed that Mercedes received an incentive tax-package of 165,000 usd per-worker to reallocate its plant into a different State (Alabama) but its cost was almost equal to 300 usd million dollar plant. Clearly, the ultimate goal of such policies is much broader than reducing fixed and variable costs like free land or industrial park sites. In fact, the combination of entrepreneurial policies (e.g., programs to promote to R&D, research on science conducted by universities, etc) are also important factors that may enhance regional labor markets and foremost avoid the lavish of scarce public funds.

software production and online services. Thus, capturing a large market share with a relatively small workforce (e.g., Facebook or Google).

In the same way, there has been a decline in the dispersion of new firms activities around the new millennium, particularly in the high-tech and information industries with large skewness-driven declines (Decker et al., 2016*a*,*b*).[5] Also, the global labor share has been declining significantly since the early 1980s —for different industries and across countries— due to the lower price of investment goods and capital augmenting technologies (see, for example, Karabarbounis and Neiman (2014) and Kehrig and Vincent (2018) for a manufacturing analysis).

In addition, markups for the high-tech and manufacturing industries have been rising during 1988-2015. However, the level of concentration in the former sector rose sharply (especially after 1995) with respect to the latter which remained more stable across the same period of analysis (see, for example, Hall (2018), Crouzet and Eberly (2018), De Loecker et al. (2020), among others). Likewise, decreasing investments, lack of technological opportunities and economic shift activities away from manufacturing (mostly to services) cope with the rise of "superstar firms" could have had an impact over labor productivity and firms' innovation activities. As a result, industries are now more sensitive to supply side labor policies. More precisely, there is a negative impact on labor productivity in industries where firm specificities and tacit knowledge are the main ingredient for innovative competencies. Hence, all knowledge tends to be concentrated in people, leading to high rates of labor turnover and making knowledge accumulation more difficult (Kleinknecht, 2020).

Nonetheless, in light of the current state of the U.S economy, is there still room for infrastructure investments? Nowadays, infrastructure and regional development are considered from a multidimensional perspective. In fact, not only geographical patterns or intangible assets matter, but also innovation policies as well. Indeed, the latter are important as they support the proliferation of new startups activities and at the same time, they encourage entrepreneurs to take advantage of new opportunities in the form of capital knowledge e.g., broadband investments (Audretsch et al., 2015).[6] Therefore, the implementation of large public infrastructure projects, could be regarded as labor enhancement policies for regional economies in terms of new jobs and better salaries and/or potential incubators for the development of high-tech industries like computer and electronic product manufacturing, telecommunications, ICT, among others.

[5]Even after controlling for firms' size, age and industry's type, these results only accounted no more than one-third of the decline in job reallocation (Decker et al., 2014).

[6]Innovation effects are not uniform because firms located nearby better transportation networks can absorb more resources from those investments than laggard ones located in distressed regions (Cohen and Levinthal, 1990).

Following the previous line, a recent work of Bennett (2019) takes an intermediate venue by analysing entrepreneurial dynamism and infrastructure provision (public and private) across U.S states. Surprisingly, he finds a negative relation between public infrastructure and business dynamism. In broader terms, job-destruction rates are positively affected by public provision whereas the converse occurs for private infrastructure and job-creation rates. Despite not regarding an industry analysis nor formally considering innovation activities, his results suggests that in the former case, public infrastructure works as an entrepreneurial "disabler" whereas in the latter, private infrastructure functions as an "enabler" of business entrepreneurship. For what concerns wages, a recent paper of Kemeny and Osman (2018) focuses on the differences between tech and non-tech jobs controlling for occupational skills and job characteristics (e.g., creativity, originality and schooling requirements). Yet, their empirical analysis disregards the effect of infrastructure investments and authors fail to find any systematic difference between different type of jobs. Therefore, these results can be considered a puzzle.

This paper fills the gap of the regional development literature by examining infrastructure investments (public and private), State incentives (monetary and non-monetary) and innovation outcomes (i.e. technological patents and scientific citations) in the U.S. One of the novelties of the present paper is the inclusion of non-monetary incentives (given by the diffusion of past public policies applied since the 1913's) and the production of technological patents conditional on industry subsectors value share to examine the performance of regional labor markets in terms of new jobs and better salaries. In empirical grounds, the paper aims to answer two questions: Can development incentives (e.g., R&D tax-credits) or else non-monetary incentives coupled with infrastructure investments (both public and private) boost job creation rates among industries? If so, how effective are these policies and foremost in which industries those effects will be larger? Furthermore, to what extent infrastructure, incentives (monetary and non-monetary) can influence the (conditional) wage distribution of (within) industries? To put the discussion into content and address those questions, I first identify the sectors for which infrastructure and innovation policies have the largest effects: high-tech industries like computer and electronic product manufacturing, telecommunications and ICT. To our understanding, its inclusion hinges upon two major reasons.

First, regional employment rates are expected to be benefited from high-tech firms as these industries increase regional aggregate value shares. Second, these group of industries can generate different forms of agglomeration economies and thick market externalities. Thus, its proliferation may lead to sizeable effects in terms of new jobs and salaries for regional labor markets (see, for example, Moretti and Wilson (2014, 2017) in the R&D and biotech industries).

Then, I propose a simple regional model in which workers have some kind of mobility and firms make use of both type of incentives: monetary (e.g., tax-credits) and non-monetary (the mere diffusion of past public policies) in order to highlight the channels.

The first contribution of the paper is the identification of important stylized facts from the U.S business slowdown (e.g., higher knowledge gap and lower market competition between top and bottom innovators in public firms). That is, firms with lower marginal costs are more likely to be benefited from these public policies. The second contribution is an empirical assessment of the channels for which the above-mentioned policies work in regional labor markets. To this end, this paper employs Instrumental Variable (IV/GMM-HAC), Instrumental variable with arbitrary clustering (IV-AC), Spatial Lag Models (SLX) and Instrumental Quantile Regression (IQR) methods. I find that both types of incentives coupled with non-residential private spending have a positive business "enabler" entrepreneurship effect on employment rates in top value-added industries while public highway expenditures display a "disabler" effect only in sectors with lower value share. Interestingly, the cumulative response of generous state subsidies and R&D user cost are positively associated to higher job creation rates in bottom rather than top value-added sectors. However, when spatial variables are introduced into the analysis, I find positive (direct) effects of public infrastructure and insignificant ones for private infrastructure in total high-tech employment. Finally, interactions between non-monetary incentives and innovation outcomes in high-tech sectors with a higher aggregate value share are positively associated to employment networking (spillover) effects in other states provided that firms stimulate their local economies through increasing rates of ideas (i.e. production of technological patents) due to generous tax-credits. These trends are also observed in high-tech wages in sectors where marginal costs are already lower. That is monetary incentives imply additional cost-saving effects for high-tech firms and workers in those sectors have on average better salaries while a higher policy score does not imply better salaries. Therefore, the median worker in lower value-added sectors benefits more (on average) from these public policies as his/her salary is higher compared to those in top value-added sectors.

Overall, this is paper makes important contributions to the "jobs to people" literature as it links infrastructure, past public policies effectiveness and innovation outcomes in high-tech sectors where agglomeration economies and thick market externalities are considerably larger with respect to traditional industries related to these type of investments (e.g., construction). Thus, the empirical evidence in this paper is an important departure from the "beggar the neighbour effect" (see, for instance Wilson, 2009) because infrastructure investments couple with incentives both (monetary and non-monetary) indirectly generate positive spillover effects in other high-tech industries. From a state's perspective, efforts should be concentrated on the empowerment of laggard high-tech sectors, the reduction of the innovation/wage tech gap and investing R&D subsidies and federal grants into new low-cost technologies, job-training programs and/or dynamic processes based on worker's capabilities with soft skills. To the best of my knowledge, this paper is the first attempt to unpack employment and wages relations from infrastructure expenditures (public and private), development incentives and innovation outcomes (i.e., patents and scientific citations) at a regional level for industries with different aggregate values.

The rest of the chapter proceeds as follows. Section 2.2 discusses the relevant literature. Section 2.3 outlines a simple model and the econometric approach. Section 2.4 discusses the empirical results. Finally, the paper concludes in section 2.5 and offers some policy implications.

2.2 Related Literature

Infrastructure investments coupled with the presence of local monopolies that restrict the flow of ideas to others, allow the internalization of innovation through technological waves. In plain words, entrepreneurship entails innovation because the essence of capitalism is to evolve i.e. to seek new combinations —of products, production processes, new forms of organizations and economic opportunities— while destroying the existing ones in a creative way while reallocating these resources into the highest valued use (Schumpeter, 1934, 1942). Others instead consider that the most important transference of knowledge comes from the outside (Jacobs, 1969). That is public policies like infrastructure expenditures provide the ingredients to boost regional convergence (Armstrong, 1995) through increasing rates of innovation activities among firms, new establishments, jobs and/or better-paid salaries for local economies.

In the case of infrastructure, whether we regard the public: "broad" (health, justice, education, transportation and facilities), "core" (highways and bridges, air transportation, sewage systems) or the private[7] definition (e.g., non-residential spending), they all support and facilitate diverse activities performed by workers and firms (Miller, 2013). Indeed, these traditional expenditures not only stimulate the proliferation of new establishments, but also they may produce sizeable effects through increasing rates of innovation, changes in the wage structure among industries, among other factors.

Nevertheless, at a macro-regional level the effects of infrastructure investments over labor markets are mixed. For instance, considering a universe of 12 industries, Pereira and Andraz

[7]Even though infrastructure is a non-rival good subject to congestion, private firms usually invest on these projects as a mean to: 1) reduce delivery times; 2) improve their plant (capacity) in the manufacturing of goods and services and 3) decrease their production costs (technical efficiency).

(2003) find that highway expenditures can shift the sectoral composition of employment in the construction, durable manufacturing and transportation industries. Conversely, private investments may foster the overall pace of employment reallocation in manufacturing, public utilities and communications sectors. In broader terms, public infrastructure investments affect private employment positively in only six of the twelve industries under consideration while private investments in only five. Furthermore, public investments tend to be absorbed disproportionally more in bigger states (Pereira and Andraz, 2004, 2012*a*,*b*) and may contribute to expansion of regional asymmetries —in terms of employment growth— because the major source of funds, hinges upon the number of representatives in the senate as well as the extent of (previously) approved projects.[8]

Moreover, the work of Leduc and Wilson (2013) explores the dynamic effects of highway spending through the lens of federal grants. Yet, given that economic agents are foresighted (i.e., they may anticipate well in advanced the eventual level of grants); as a result, capital outlays tend to be slack i.e. endogeneity is likely to occur. In order to overcome this issue, authors take the expected present value of forecasts (current and future) grants as a source of exogenous variations. Overall, their impulse response analysis suggests no evidence of an initial impact over employment, unemployment or wages. Although, for some industries like transportation and retail the effects were large in the medium run (6 to 8 years out). Likewise, to account for non-linearities, they assess the validity of predicted grants for periods in which the GDP contracts or expands (i.e. recessions and expansions). Results are imprecise, hardly any difference after 8 years can be observed, though the initial impact of the former variable over employment is indeed significant. Interestingly, a recent work of Greenaway-McGrevy and Hood (2019) refines the Vector Autoregressive approach (VAR) by filtering-out the effects of common shocks like national crisis over U.S regional economies. Results show that after a shock, employment recovers in the following period. Therefore, filtering methods provide more flexibility —with respect to the Blanchard and Katz (1992) canonical approach—, to capture the spatial temporal heterogeneity of labor market indicators without including specific controls.[9]

In spite of the inconclusive evidence, infrastructure investments are paramount as they effectively influence firms' location by releasing additional resources, favouring knowledge accumulation (e.g., patents and scientific citations) and generating positive externalities in the regions where those ideas were originally developed (see, for example, Jaffe (1989), Rauch (1993) and Feldman and Florida, 1994). Nevertheless, regional asymmetries can be persistent due to lower

[8]The identification strategy subsection exploits this fact by using the number of representatives in the appropriation committee as an exogenous variation source in highway expenditure.

[9]However, an important drawback of this approach is that both the number of units N (cross sections) and T (number of time series), must be sufficiently large to consistently estimate all components of the model, a requirement that may not be fulfilled.

capital stocks (physical and human), differences on the distribution of geographic resources (e.g., land fertility, temperatures) and heterogeneous demographic characteristics like a higher proportion of qualified workers on richer regions (see Capello and Nijkamp, 2010, chap. 2 and chap. 10).

In the same way, the knowledge spillover theory suggests than richer regions are more likely to generate more entrepreneurial opportunities than poorer ones due to the context in which entrepreneurs grasp the decision-making process (Acs et al., 2013). For example, the higher the value of regional amenities offered to workers (e.g., housing quality: more space, access to fireplaces, better water systems, etc), the more concentrated will be the creation of knowledge as (the share of) high-skilled workers will choose to live in the nearby of metropolitan areas. Hence, fostering job-creation rates among firms but also influencing the wage-premia across regions (Moretti, 2013).[10]

For what concerns incentives and funding sources, taxes reflect (at least partially) the opportunity cost of infrastructure spending. In addition, an excessive fiscal burden can increase or reduce land value through regional amenities (e.g., better highways, sewage systems,etc) and foremost influence innovation activities performed by firms. Therefore, taxation affects the location of both workers and firms giving rise to several effects over regional economies. In that vein, the empirical evidence is also mixed.

Studies show that State incentives or "jobs-to-people" policies in the form of: investment credits, R&D stimulus, property and job-creation tax-rates, are far more efficient than "people-to-jobs" (i.e., out-migration subsidies) because encouraging people to leave those regions not only reduces the demand (i.e., through less households spending), but also it produces a negative effect on the supply side through lower housing prices and decreasing construction rates. Thus, as population densities decrease, more jobs will be destroyed generating a negative impact over individual's wealth. For example, ever since the 1990's, incentives have tripled and they have been intensified (e.g., Wisconsin's Foxconn manufacturing $3 billion plant) and yet employment rates have remained stable across time (Trogen, 1999). In that same line, Garin (2019) find that the ARRA event study program effects were slightly positive and close to zero at an aggregated level. For instance, in the short-run for each dollar spent on the construction sector in the year 2010, six jobs were created per $1 million.[11]

[10]Of course, due to the unobserved ability among college workers, this wage-gap could be biased downwards or upwards although these differences are generally orthogonal from housing costs.

[11]According to Ramey (2020), there were at least two facts for which the ARRA was not effective. First, at that time, interest rates were closely to zero (lower zero bound). Second, unemployment rates were on average 9% to 10%. Hence, it appears that the monetary (accommodative) policy applied by the FED may have wiped out the potential benefits of the program leaving slightly positive or either negative effects.

Studies empathize that generous tax-credits have a positive but limited effect over sectoral employment and innovation. For instance, focusing on the U.S biotechnology industry at both margins[12] (intensive and extensive), Moretti and Wilson (2014) show that development incentives through R&D subsidies raise the number of star scientists. However, most of these gains are the consequence of state-adopters relocations with limited effects on incumbent scientists productivity. In terms of total employment, they uncover significant (positive) gains in the Pharmaceutical and Medical sector (16%); the Pharmaceutical Preparation Manufacturing (31%) and the scientific R&D industry (18%) and almost no effect or close to zero for salaries in those sectors. However, despite considering tradable and non-tradable sectors outside the biotech (e.g., high-tech industries like chemical, machinery manufacturing), the inclusion monetary incentives are insignificant different from zero or negative, suggesting no stimulative effects over employment. Surprisingly, efficiency gains on the R&D user cost were insignificant in all cases. A possible explanation offered by the authors is that scientists in those sectors represent a smaller share of total employment compared to the biotech industries or possibly their labor supply is more inelastic.

Interestingly, new evidence shows that monetary stimulus give residents extra-job experience and can influence regional income distribution, generating positive spillover benefits even in the reduction of crime and child development (Bartik, 2019*a*). However, they may also lead to fiscal externalities by inducing firms and workers to reallocate. These decisions, impact the demand and supply of labor, which ultimately hit population, income distribution and the labor market. In this line, Bartik (2019*b*) points out at least three reasons for which those policies have not been effective at stimulating regional and local labor markets.

First, they are not target-oriented to distressed places (e.g., Indiana and Illinois have the same employment rates but the former receives twice of the economic incentives). Second, the extent and the scope of incentives is extensive are fairly dispersed to all kinds of firms. Indeed, the average duration of incentives is about 10 to 15 years —a period beyond business owners and young firm survival rates— and foremost, they are not focus on the major source of employment growth (i.e., high-tech industries).[13] Third, public policies that are not aimed at

[12]This paper main focus is based on the intensive response (employment growth) to specific shocks: highway expenditure and development incentives (monetary and non-monetary) as a proxy of innovation policies. For what concerns the other margin, empirical evidence suggests that most of the variation comes from the extensive entry margin, not from the behavior of incumbents. In other words, a local shock increase wages, attracts more workers to the area spurring the creation of new entrants. Hence, the created externalities propagate an amplify the process of firm creation by reducing exit rates. The latter pattern is also captured when firms are large, have fat tails and perform external innovation activities (see, for example, Walsh (2019) and Cao et al., 2020).

[13]Another important drawback of development incentives is that current schemes are biased towards large firms rather than small ones. In that way, downstream employment creation is unlikely to be successful because for the latter type of firms, business reallocation becomes more costly. Hence, in order to improve tax-incentives effectiveness, federal intervention should be considered.

improving firms' inputs (e.g., updating roads or other public infrastructure services) can spur job-creation rates and ultimately offset the full potential benefits of development incentives. In fact, given the complementary between firms' inputs and infrastructure expenditures, improvements in productivity may boost even more regional economies if tailored-business services have a considerable weight on labor markets. For instance, manufacturing extension services or customized job-training programs by community colleges supported by federal aid, can provide advice to smaller manufacturers on adopting new low-cost technologies, target-specific market research or better soft-skills for profitable business networking. Accordingly, the combination of both tax-incentives and infrastructure expenditures might lead to increasing returns of employment growth if the workforce is highly skilled and trained. Certainly, as the number of available jobs augment, state policymakers could make use of those additional resources for more job-training programs.

On the other side, tax evidence shows that narrower tax-bases not only discourage firms' entrance, but also reduce the expected net profits from specific locations (e.g., a higher cost of living), employment rates and real wages (Serrato and Zidar, 2018). Albeit, the pace at which firms enter onto the market have important macroeconomic consequences, the effects of a smaller tax base over employment rates and real wages will ultimately depend on the state income incidence by workers, landowners or firms owners.[14] For those reasons, tax-cuts towards lower or moderate income groups within a spatial discontinuity framework instead of taxing the top 10% "wealthiest" decile are more effective to increase employment rates (see, for example, Ljungqvist and Smolyansky (2014), Zidar (2019), among others).

For the same token, taxation produces a negative effect over innovation outcomes and may lead to human capital reallocations. In this line, Akcigit et al. (2018) show that the elasticity of innovation in the U.S (measured by patents and citations) with respect to both taxes (personal and corporate) at a macro (State) level is higher for workers inputs (expenses and effort) as a result both factors become more costly. Accordingly, inventors will decide how much effort to assign to their own work and companies will choose the amount of qualified workers to hire. For those reasons, each state might have a different response to infrastructure provision due to citizens/firms heterogeneity in regards to the potential benefits in different states and/or bordering counties. For instance, high-productivity inventors could "shirk" at their workplace because shared profits with firms are not attractive. Therefore, regardless the tax-base provided

[14]For instance, Amior and Manning (2018) claim that employment rate can be expressed as a "sufficient statistic" i.e. all workers are renters, so housing costs can only affect welfare through real consumption wage or a local projection mix of employment. However, if residents are also owner-occupiers, then, housing becomes mobile and changes in housing prices may curb population after controlling for employment rate. Clearly, the sign of this effect is ambiguous, but as authors explain, the inclusion of that variable does not seem to be statistically significant.

by each state, firms would be willing to offer lower wages, or else inventors might abandon firms in the search of more profitable opportunities in other regions or more precisely, the so called "business stealing" effect.

In spite of the negative effects of taxation, policies should be targeted at the most innovative industries.[15] Earlier studies at a micro level (see, for example Haltiwanger et al. (2014, 2016), among many others) documented that after the 2000 period, young high-tech firms were responsible for more than 20% of new jobs. However, their rate of survival is not long enough (5 years or less) and above all, the rate of created jobs decreases monotonically with firm size.

Others instead argue that high-tech firms generate more profitable opportunities for entrepreneurship and employment growth because it is less expensive and less time consuming for geographically separate individuals and firms to acquire new learning skills and come up with the development of brand new technologies. Hence, regions in which institutions have a better performance, are more likely to provide high-quality public goods (e.g., highways), affect entrepreneurship dynamics (i.e. innovation spillovers) through governance indicators and better access to capital (see, for example, Williamson (1998), Acs et al. (2008), among others). More recently, Tuszynski and Stansel (2018) find a positive and significant relationship between economic freedom and entrepreneurial activity in the U.S (measured as granted patents per 100,000 population) but a negative robust relationship between patents activity and the sum of economic incentives: property tax, job-training grants, job-creation, tax-credit and research & development when establishments are "small" (less than 10 employees) while the converse is observed for "large" firms (i.e. those with more than 500 employees). Accordingly, the institutional environment in which entrepreneurs interact among each other curbs innovation incentives. That is lesser regulations in the labor market coupled with a reduced government size in terms of taxes and spending and development incentives, strengthens business entrepreneurship in the short-run by enhancing job-creation rates with mixed effects over welfare depending on establishment size.

On top of the above-mentioned evidence, Bartik and Sotherland (2019) claim that regional employment is expected to be benefited from high-tech firms because these firms can generate different forms of agglomeration economies. Thus, the larger the place and/or concentration

[15] The definition of which sector belongs to the high-tech category is not exempt from drawbacks. In fact, according to the BLS, an industry corresponds to the high-tech category only if its employment share exceeds twice the overall national average (with the special focus on science, engineering, and technician occupations). Yet, as firms gain market power, labor shares decrease and output falls; thus, real wages will follow that trend because prices are higher (De Loecker et al., 2020). Therefore, the share of industries varies across time because highly qualified workers may abandon firms in the search of more profitable opportunities. As a result, since one of our concerns is related to the distribution of innovation in terms of aggregate value, we take a standard approach in considering all industries within the software and telecommunication sectors. To this end, we follow the strategy suggested by Hall (2018). In broader terms, our choice is not that far from Bartik's new labor shares estimates (the Appendix B of the aforementioned paper lists the new ranking of high-tech industries).

levels of these type of industries, the higher will be the spillovers and employment clusters. Moreover, high-tech firms may contribute even more to the development of laggard labor markets if the initial employment-share is around 10-15%. In fact, there is a threshold effect beyond the upper bound (15%) in which the high-tech multiplier is modest or it does not lead to employment growth. Therefore, agglomeration economies may have diminishing returns (i.e., a sort of an inverted u-shape) or congestion effects could deter employment growth. Or else, it could imply the presence of gap between the arrival of a shock and firms' response in regards to agglomeration economies that foster productivity and wages.

For the same reasons mentioned above, industry wages should not be disregarded from the analysis as high-tech sectors are constantly evolving over time. Certainly, infrastructure investments can be regarded as a sort of "amenity" (e.g., reducing time distances) for all type of industries (including the high-tech) as it is a non-excludable good. Earlier studies show that infrastructure expenditures benefit both manufacturing and retail industries attracting additional workers and in-migrants towards more developed regions, boosting employment rates and foremost increasing real wages without offsetting private sector productivity (Dalenberg and Partridge, 1997).

Furthermore, new evidence suggest that even though young high-tech firms bring employment and innovation gains over labor markets, these effects tend to vanish as firm grow in size and age (Santoleri et al., 2019). In other words, there is a positive (though heterogeneous) effect of innovation activities (R&D expenses and granted patents) over the conditional distribution of employment. Nonetheless, throughout quantiles employment rates increase during the first years but as firm grow old, they tend to diminish. In the case of patents activity, employment growth is positive and statistically significant starting from the 30^{th} up to the 90^{th} percentile with a particularly larger effect over newborn firms. Therefore, the solely addition of new establishments and/or an increase in the pace of innovative activities, do not necessarily imply more jobs nor higher real wages. Interestingly, Kemeny and Osman (2018) explore the wage gap between tech and non-tech activities controlling for a set of occupational skills and job characteristics (e.g., creativity, originality and schooling requirements). Results show that the effect of tech employment on real wages does not vary across different levels of characteristics. In addition, despite restricting the analysis to very high-paying jobs (e.g., finance and insurance), the difference between tech and non-tech remains unaltered which could be considered a puzzle.

For those reasons, the present paper provides an alternative explanation and argues that an uneven distribution of aggregate value share within high-tech sectors could explain such puzzle.

In plain words, as we will later show, there is an heterogeneous effect over the conditional distribution of wages due to monetary and non-monetary incentives (for more details see subsection 2.3.2). Instead of assessing the effect of individual policies, we hypothesize that infrastructure expenditures, R&D tax-credits, the production of scientific knowledge (conditional on aggregate value share) and the diffusion of public policies may explain the asymmetries of high-tech firms (i.e., small and large) in terms of aggregate value share and foremost in which sectors the effects over regional labor markets (employment and wages) will be higher.

Accordingly, in order to identify the casual response of regional labor markets to different shocks, an econometric model will be presented in the next section. Broadly speaking, infrastructure investments (public and private); monetary incentives (R&D tax credits); non-monetary ones like the mere diffusion of public policies in the fields of education, labor markets, domestic commerce; and innovation outcomes measured by technological patents and scientific citations conditional upon firms' aggregate value share may be influencing regional labor markets through several and (possibly) opposed channels: 1) geographical (e.g., temperatures and regional characteristics); 2) socioeconomic (e.g., high-school and college graduation rates); 3) institutional quality (e.g., labor market friction index) and 4) supply shocks (e.g., recessions). As a result, employment rates could shift upwards or downwards depending on the extent of each channel. Thus, we assume that workers have some kind of mobility. Yet, highway outlays can be correlated to employment measures (i.e., endogeneity). To this end, in lieu with extant empirical literature, we appropriately address this issue by regarding the number of senators in the committee members as a source of quasi-exogenous variation for infrastructure spending (further details are in the identification strategy subsection 2.3.2).

To conclude our empirical analysis, we exploit high-tech heterogeneity to assess the possibility that the above-mentioned channels may have a different response at part of the wage distribution. Simply put, one may wonder to what extent conditional quantile wages are affected by changes in state policy interventions, like infrastructure investments and per-capita patents relative to industry's value share and/or the mere diffusion of past policies. Overall, the aim of this exercise is to identify the most profitable sectors in which those policies have the largest impact over regional labor markets.[16]

[16] Of course, there are many other factors that certainly affect the wage distribution. For example, the presence of stringent regulations (e.g., minimum wages , workers' licenses), degree of (de)unionisation, workers' occupation, industry market power, gender inequality, etc. A comprehensive study of infrastructure expenditures considering all those aspects is beyond the scope of the current paper.

2.3 Econometric Approach

Our empirical strategy relies on the workhorse of urban economics studies Roback (1982) and Gyourko and Tracy (1989). In this context, we focus on the effect of both monetary and non-monetary incentives over regional (state-level) labor markets for high-tech firms. The research questions are tackled in the spirit of "jobs-to-people" policies in which local policymakers stimulate their economies through infrastructure expenditures (public and private) as well as generous subsidies incentives (R&D tax credits) towards firms. In this vein, we regard all U.S public firms related to the software and telecommunication industries (high-tech).

One of the novelties of our approach is the inclusion of non-monetary incentives proxied by a score on the diffusion of past public policies in several fields (e.g., education, energy, environment, domestic commerce, etc) as *innovation boosters*. In broader terms, the introduction of both type of incentives not only generates *direct effects* over regional labor markets (e.g., more jobs and payrolls), but also it may increase the production of scientific knowledge (i.e., technological patents) conditional upon the share of aggregate value within the industry. For instance, sectors with lower marginal costs like software production and/or online services are more likely to generate more knowledge clusters.

For what concerns the *indirect effects*, we are aware that agglomeration economies (e.g., higher local multipliers due to incentives) outside high-tech sectors as well as different responses at the extensive margin could be at work (e.g., new birth establishments). In this line, as explained earlier, the aim of this paper is to assess the cumulative response of infrastructure and innovation policies only at the intensive margin. Therefore, we will not pursue that road when performing the econometric analysis.

Having mentioned the facts from above, before proceeding to the econometric model, a simple model is proposed in Figure 2.1. For the sake of the brevity, we leave the formal proof outside but we briefly explain its intuition. Let us consider a world in which workers maximize their utility from a composite good (Q), land (N), a vector of natural amenities (A), infrastructure services (G) with an inelastic labor supply (for the ease of the analysis). At the same time, firms maximize their utility (choosing labor) given wages (W), taxes (τ), a vector of local amenities (A), making use of infrastructure services like highways (G) with free entry/exit (long-run) which implies profits equal zero. In addition, if we assume additive separability and conditional independence with forward looking decisions (Bayer et al., 2016) and solving for employment taking as given a set of past location characteristics, then it is possible to disentangle the direct and indirect effects of both types of incentives (monetary and non-monetary).[17] Accordingly, we will have the following effects onto labor markets.

First, the adoption of monetary incentives in the form of R&D tax-credits towards local markets directly increases the size of the industry as it curbs inventors incentives to remain in the area in which those benefits are granted. Yet, as explained before, there is an heterogeneous and higher response of innovation elasticicities to taxes at a macro level (Akcigit et al., 2018). Thus, despite offering positive incentives some skill-workers may be tempted abandon the region —possibly in bordering counties— in the search of more profitable opportunities. Hence, employment effects could be partially offset by this fact. In practice, regardless the industry under consideration, innovation is usually measured as the number of star scientists at a state-level (i.e., those in the upper distribution). In our case, we consider the conditional distribution of patents and scientific citations —in terms of industry aggregate value share— at each percentile under both types of incentives: monetary and non-monetary.

Strictly speaking, our framework includes R&D tax-credits, firms user cost, infrastructure services (both public and private) as well as the mere diffusion of past policies and/or per capita patents as innovation boosters for regional labor markets. In the case of public infrastructure a public good subject to congestion, new expenditures support and facilitate diverse activities performed by firms as these imply a reduction in labor costs. Hence, additional resources (a priori) could be assigned to more research activities and job training programs. Nonetheless, the creation of knowledge takes time as it cannot be diffused rapidly. Put differently, delayed and cumulative effects are more likely to be present as the potential benefits of lets say a new highway may fully be visible in the medium or long-run (a minimum of 5 to 10/15 years). As a result, we expect displacement (mostly negative effects in the short-run)[18] cope with positive ones (human capital, improvements on the quality of institutions and/or spillover effects) in the medium/long-run. But in broader terms, we can expect an entrepreneurship enabler effect of private infrastructure as it can also facilitate the development of diverse activities and foremost generate cost saving effects.

Using our simply model we can observe that both types of incentives (monetary and non-monetary) may coexist simultaneously in the sense that they can stimulate innovation activities and increase aggregate value of the industry. In this vein, private capital investment in any form

[17]Note that we have made the strong assumption that local governments have an objective function and choose to subsidize those firms for which their potential aggregate value share may provide future benefits to their local economies. Since high-tech incentives impact all firms user cost, only local representatives can decide the implementation of tax-cuts of fiscal benefits for their economies. Hence, we might separate public firms in terms of aggregate value before the implementation of any incentive program.

[18]Another channel that produces a negative shift in local markets is out-migration or people-to-jobs subsidies. As we stated before, encouraging people to leave regions not only reduces its demand spending, but also it produces a negative effect on housing prices. Hence, as population densities decrease, more jobs are destroyed generating a negative impact on regional income. Likewise, the same effect is at work when a contraction in the national economy takes place.

is the bridge between jobs creation and better salaries which is also consistent with targeted policies to distressed places or jobs-to-people that lead to an increased demand for goods and services.

Last but not least, it is noteworthy that our conceptual framework uses arrow dots to empathize conditional relations which in our case hinge upon each sector contribution (in terms of aggregate value share) from the national economy. Clearly, at a regional level it will depend on the interaction of several and possibly opposed channels. Along these lines, our theoretical road-map assigns indirect effects in regards to innovation and employment outcomes. To this end, high-tech value share is the vehicle for which different subsectors (with different marginal costs) create more jobs.

Finally, the approach employed in this paper relies on the large body of existing evidence (e.g., Moretti and Wilson, 2014). Certainly, it makes sense to have some kind of mobility among highly educated workers (i.e. elastic labor supply). However, this degree of mobility may not have to be the identical within each subsector. As a result, we expect an heterogeneous conditional response on payrolls based on incentives and their corresponding value share within high-tech industries. In other words, infrastructure and innovation policies affect the entire *conditional distribution* of industry wages because each sector embodies workers with different qualifications and also the production of knowledge is not uniform (i.e., some states may produce more knowledge than others). As a result, the contribution of each subsector in terms of aggregate value is also different. For those reasons, our second empirical exercise examines the impact of high-tech wages to infrastructure and incentives (monetary and non-monetary) and innovation outcomes through the lens of quantile regression models (further details of the empirical strategy are discussed in subsection 2.4.2).

Employment Models

Our benchmark specification departs from the standard panel-fixed effects model. We first uncover causal relations regarding both types of infrastructure and non-monetary incentives as a proxy of innovation policies for the 48 contiguous states using different controls taken from the urban economics literature. Formally, we test the following equation:

$$y_{it} = \chi_{it} + \iota_{it} + \kappa_{it} + z_{it} + f_i + d_t + \epsilon_{it} \tag{2.1}$$

Where y_{it} is the outcome of interest: job creation rates for the top and bottom value-added high-tech industries; χ_{it} is an infrastructure vector (highway and non-residential expenditures);

ι_{it} represents the non-monetary incentives (i.e., the diffusion score of past policies net of infrastructure) and/or the conditional percentiles of per capita patents; κ_{it} is Real GDP growth rate excluding both measures of infrastructure (public and private); z_{it} a vector of urban controls named average temperature, human capital, institutions and supply shocks (i.e., economic downturns); f_i are division fixed effects and ϵ_{it} is the error component term. Additionally, since highway capital outlays vary in sample size, I include a dummy variable d_t to account for time effects. In this way, the stability of the panel given its short dimension ($N = 48$ and $T = 26$) is preserved.

Nonetheless, equation 2.1 does not capture the entire picture of our first research question. Consequently, we move on to a full specification in which we simultaneously test for employment effects under both types of incentives: R&D tax-credits; firm's user cost; non-monetary incentives (the mere diffusion a set of past policies) and/or the conditional percentiles of per capita patents along with the usual controls from urban economics models. Formally, our second equation is the following

$$y_{it} = \chi_{it} + \iota_{it} + \sigma_t + \gamma r_{it} + \kappa_{it} + z_{it} + f_i + d_t + \epsilon_{it} \tag{2.2}$$

Where the high-tech R&D tax-credit (σ) is a dummy variable equal to 1 for those adopters with positive incentives rates and 0 in contrary case. In this case, we adopt a more standard approach since we are also dealing with a common consumption good (i.e., highway). Further, we include firms user cost from U.S public firms (γr_{it}). Unlike previous studies, when measuring this variable we consider a longer time span (1965-2015) of the R&D expenditure shares which are on average half of the IRS (0.5). Moreover, since we are also interested on delayed effects, we directly allow for the cumulative response of user cost and we interact this variable with the dummy incentive to get a magnitude of monetary incentives over regional labor markets. The expected sign of the interaction is negative because when reduction in the R&D user cost takes place, it stimulates the number of star scientists at any level (corporate, private, academic) through higher saving costs; hence, realising additional resources for hiring qualified workers. Conversely, a positive user cost implies less R&D investments or less resources to investment in human capital; thereby, higher displacement effects and/or fewer star scientists amongst states. In addition, given that public capital outlays tend to be slack and incentives could be contemporaneously correlated, we allow delayed effects (up to 3 years) of the dummy variable.[19]

[19] As a matter of fact, the sum of the coefficients on current and lagged incentives yields a cumulative effect of four years. Naturally, medium run effects in regards infrastructure imply the use of more lags. But given the short dimension of our panel, our econometric models follow the empirical literature and allow up to 5 lags of highway expenditures.

Hence, we estimate a variant of equation 2.2

$$y_{it} = \chi_{it} + \iota_{it} + \sigma_{t-3} + \gamma r_{it-3} + \kappa_{it} + z_{it} + \sigma_{t-3} * \gamma r_{it-3} + f_i + d_t + \epsilon_{it} \tag{2.3}$$

Accordingly, our preferred specification will be equation 2.3. Therefore, if high-tech incentives have a positive effect on employment rates, then, $\sigma > 0$ and $\gamma < 0$. However, there are several aspects that are worth mentioning.

First, for what concerns firm's user cost, one might be sceptical about its variability and/or the degree of exogeneity with respect to the dependent variable. Nonetheless, as Moretti and Wilson (2014) claim, within each state political idiosyncratic factors as well as the implementation of incentives are not uniform. In terms of our research question, we assume that each unit can be considered independent (exogenous), but we also acknowledge the fact that development incentives hinge upon the political power of the different committees in the house of senators (e.g., small business and entrepreneurship, finance, etc) of each region. Another potential issue would arise if general incentives are correlated to unobserved differences across states for high-tech industries. If so, then, depending on the extent of such correlation, permanent differences might not be captured through fixed-effects and as result we would have a positive (negative) bias which may lead to overestimate (underestimate) the cumulated R&D user cost. Nonetheless, since we are in the presence of common consumption good (i.e., infrastructure), then, we assume that unobserved heterogeneity comes from the capacity of each firm (belonging to their corresponding subsector) to absorb infrastructure services and to re-invest those additional resources into R&D programs and hiring more workers.

Second, we introduce the notion of non-monetary incentives as a proxy for innovation policies which is novelty with respect to existing literature. Policy diffusion data can be fairly representative of state policy activity in different fields. Particularly, its use may provide more answers about the performance of regional labor markets. In our case, since we regard a set policies (excluding transportation) back from 1913's, it is likely that the smooth indicator be weakly correlated predictor to our labor market outcome. Hence, it enters into our model as an exogenous variable.

Third, as regards the effects of regional innovation, it is most likely that a positive sign on γ can be related to firm's dimension and/or an unequal distribution of their innovation activities due positive delayed effects of infrastructure investments (e.g., a higher number of senators might have led to more discretionary funds to most innovative states). In this line, we overcome this issue by accounting for the conditional contribution of each sector to the economy as a result of different absorbing capacities of infrastructure. More precisely, we weight patents distribution by their respective aggregate value share of the sector. In this way, we disentangle those sectors as the top value-added from bottom value-added.[20]

Fourth, an important fact that needs to be mentioned is the correlation among residuals and cross-sectional dependence among units. It is well known that persistence among predictors in regards to high-tech employment are likely to occur. Moreover, OLS estimates are naturally biased due to unobserved heterogeneity and cross-correlation. As a result, we account for both issues within an instrumental variable (IV) framework data following two different roads.

On the one side, we first estimate equation 2.3 using the HAC (autocorrelated and heterokedastic) correction. Then, as a first robustness control we make no assumptions about the spatial structure of the error term. In plain words, correlation within each units takes place in any possible way, without any kind of imposed structure (Colella et al., 2019). This is possible because unlike traditional spatial frameworks, groups are non-overlapping in each dimension and each observation belongs to the corresponding group. In this way, we avoid the problem of serial correlation in both dimensions (state and time) which might create mismeasurement in standard errors. Unlike the work of Moretti and Wilson (2014) in which cumulative effect are defined as the ratio of the coefficient over the pre-adoption mean (holding constant R&D tax credits), our framework employs further lags because infrastructure full benefits are more likely to occur within a period of 5 to 10 years. Thus, by assuming a flexible relation among errors, serial correlation can be ameliorated.

On the other, we estimate a Spatial Lag Model (henceforth SLX) while accounting for cross-sectional dependence (CSD). It is well known that CSD is an issue present in almost all macroeconomic datasets because of the nature of aggregate data. In this vein, depending on the DGP, the presence of common, time varying relationships, etc, several strategies can be considered (see, for instance Pesaran (2006), Gunnella et al. (2015), Bailey et al. (2016) among many others). In the case of short unbalanced panels like the present paper, the above mentioned strategies do not apply given that the number of units and time span should be relatively large. Literature provides evidence that filtering methods are consistent in the presence of both weakly and strongly correlated panels (Greenaway-McGrevy et al., 2012). Accordingly, a simple defactoring procedure may be sufficient to reduce the extent of common factors and strong CSD among units. Following Bai-Ng filtering methods (Bai and Ng (2002), Bai (2004) and Bai and Ng, 2004), I applied the BN criteria to the (standardized) first difference dependent variable

[20] Another strategy would be to regard deep historical innovations as a weakly correlated predictor of (current) high-tech wages due to different levels of the technological frontier (Petralia et al., 2016). However, this type instrument is time-invariant and foremost to be informative, it requires that both cross-sectional and panel estimates be sufficiently large to be compared. In our case, we focus on innovation outcomes from a small group of U.S high-tech public companies whereas historical corporate patents could be classified under several industry codes (i.e., one firm could be registered under several activities). Hence, since infrastructure expenditures is one of our major shocks, we simply use its past lags as a predictor to account real wage effects.

(high-tech employment) provided that the DGP may be explained by an AR(1) structure process (which applies to this DGP) yielding 3 factors according to the IC2 criteria.[21] However, it is worth stressing that first-difference filtering requires no gaps on the variable of interest. For that reason, the empirical results of the SLX model are based on the overall response of high-tech employment and not by our value-added classification. Similarly, the inclusion of conditional percentiles are also subject to the same problem. Therefore, I include dummy variables for each high-tech sector to support the stylized facts and the previous empirical (non-spatial) results.

2.3.1 Data Description

When exploring infrastructure and innovation outcomes over private employment for the high-tech industry, this study combines different datasets. Our main shock (public infrastructure) is constructed using the capital outlays of highway spending which includes the following items: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal (Pierson et al., 2015). In doing so, we follow other studies (Hooper et al., 2018) that make use of the same specific expenditure. Likewise, we are also interested on private infrastructure responses over labor markets. Hence, we include non-residential spending as a proxy of private infrastructure. Overall, our infrastructure measures (public and private) rang from 1990 to 2015 although the latter variable is only available from 1993 onwards.

An important task is to compute real measures. A usual practise is to divide nominal expenditures by a state price index provided by the Bureau of Economic Analysis (BEA) which takes into account the price of investment goods (for more details see table 3.9.4). Conversely, we deflate private infrastructure using the Bureau Labor Statistics (BLS) consumer price index (CPI-U 2012=100). What is more, in order to control for the business cycle effect, both spending variables are defined in per capita and later transformed into logarithms (Dupor, 2017).

For what concerns innovation, we rely on two measures. Firstly, we concentrate on the conditional distribution of innovations from high-tech industries. In other words, we take the weighted percentiles of the entire distribution of patents and scientific citations using the share of aggregate value of U.S public firms in 2001 (Crouzet and Eberly, 2018, Hall, 2018). In lieu with economic literature as well as the U.S. Patent and Trademark Office's (USPTO), we rescale patents per 100,000 population. Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020) and complemented with Arora et al. (2017). As regards the definition of high-tech sectors, we regard a more traditional approach and consider all software and telecommunication sectors at three-digit NAICS and KLEMS levels.

[21] If the process does not exhibit strong serial correlation, then, the LSDV filtering outperforms the first-difference approach.

However, a few limitations of our innovation measure are worth discussing. First, our universe of public firms represents a small fraction of the high-tech industry from national economy. In our case, we picked-up patents and scientific citations from 1,439 public firms which perform several activities related to our high-tech classification. As a result, our empirical estimations will regard the total number of patents and scientific citations from the aggregate sector and not by subsectors due to the lack of observations. Second, in order to have a clear picture of the industry in response to different public policies, it would be desirable to have information from both types of firms (public and private). In that line, the work of Dorn et al. (2020) presents a promising avenue for future research on the drivers of private innovation.

A dynamic innovation and policy diffusion score across U.S states of different public policies applied since the beginning of the 1913's is computed (Boehmke et al., 2020). We construct a smooth index for each state depending on the type of policies adopted. We focus on macroeconomics, labor, education, environment, energy, housing and domestic commerce policies leaving aside transportation since our goal is to highlight the interaction of monetary, non-monetary incentives and innovation outcomes over regional labor markets. Overall, our reduced policy diffusion score encompass a total of 204 policies (for further details of the policies and years see the Appendix A.2).

As regards private employment and industry wages, our preferable source is the Quarterly Census of Employment and Wages (QCEW). Data is based on administrative records (state Unemployment Insurance payroll reports) covering all employers with no minimum thresholds and/or flag data for employer size. Hence, they contain minimal measurement errors. Unfortunately for the latter, the universe of firms is narrow. Accordingly, we complement the payroll from County Business Patterns (CBP) as it provides more information. However, data requires an adjustment because it was measured under different industry classifications between 1990 and 2015. Therefore, we take the weights from Eckert et al. (2020) and adjust all SIC values into NAICS 2012 levels.

For what concerns monetary incentives, we follow the existing literature on tax-incentives and employment by taking R&D tax-credits from the Panel Database of Incentives and Taxes (PDIT) from the Upjohn Institute for Employment Research (Bartik, 2017).[22] In addition, we create a dummy incentive for all positive R&D tax-credits since high-tech firms perform several activities which on average are affected by general incentives. We adopt this strategy because infrastructure is a common consumption good and we have a universe of public firms.

[22]We have also collected other development incentives like job-creation tax credits from the same database. However, empirical evidence that looked specifically at the impact of those incentives and for instance job-training programs, did not find a positive significant relationship (Bremmer and Kesselring, 1993). In addition, when using the total amount of incentives the findings of Tuszynski and Stansel (2018) suggest a negative and significant relation in regards innovation outcomes (i.e., patents per 100,000 resident in that state).

In addition, we are also interested on firms' user cost. To this end, we rely on cross-state R&D data (see, for instance, Moretti and Wilson (2014) and Serrato and Zidar, 2018). Nonetheless, instead of using the expenditure share(s) from IRS which is equal to 0.5, we employ a longer time-span (1965-2015) from COMPUSTAT which is a half of the suggested by Wilson (2009) without altering their main assumptions. Hence, our expenditure share is about half i.e. 0.1243 for the upper bound (90th percentile) between the above mentioned period. In this way, we control for the influence of potential outliers in our sample. Moreover, we conduct the same empirical exercise of Moretti and Wilson (2014) by regressing in the first stage the R&D user cost on state and year fixed effects and in the second, the predicted residuals on state R&D tax credit rate. Comparing the results in terms of the R-squared from that latter regression, our was 0.369 whilst theirs 0.345 which suggests that all within-state variability of monetary incentives comes from the interaction between R&D tax credits and firms' user cost.

Last but not least, we enrich our database with several labor market indicators from the BLS like civilian non-institutional state employment population, unemployment rate and population density using the Census maps. Also, we have taken the usual controls from the urban growth literature like average temperatures in winter (January), summer (July), high school and college graduation rates from total state population (Frank, 2009). Furthermore, we have also considered the effect of minimum wages changes over high-tech sectors. However, in the U.S for many states the minimum wage legislation allows that state levels go beyond than federal ones. As a result, we include a dummy variable equal to one for years in which state minimum wages were higher than federal ones. Data for historical state minimum wages are from Vaghul and Zipperer (2016). Unlike earlier studies that focus on the effect of minimum wages outside tech sectors, here our scope is to control for minimum wage changes when both types of incentives (monetary and non-monetary) are simultaneously considered. In this way, we pick-up public policies effects over real wages for our two high-tech well defined groups (for more details see Appendix A.4).

Finally, we take the Economic Freedom of North America (EFNA) subnational summary scores to account for the institutional environment among states (Stansel and McMahon, 2018, Tuszynski and Stansel, 2018). The index is composed of 10 variables divided into three areas: government spending, taxation, and labor market freedom and each category has its own indicator (e.g., labor market regulation score is baed on the Minimum Wage Legislation, Government Employment as a percentage of Total State/Provincial Employment and Union Density). At last, we control for supply side shocks by including a dummy variable equal to one when the economy had downturns periods (e.g., 1990-91; 2001 and 2008-2010) and zero in contrary case.

All details of the variable definitions used in this paper are described in the Appendix A.1.

2.3.2 Descriptive Statistics and Correlations

In light of the empirical evidence of "superstar firms" and the U.S business slowdown, policymakers one may wonder to what extent infrastructure and State incentives (monetary and non-monetary) could have led to an uneven distribution in the production of knowledge (i.e., patents) in terms of aggregate value share. Furthermore, if between gap between top and bottom value-added high-tech firms implies a different response in employment growth and real wages as a result of the implementation of such public policies. Accordingly, prior to presenting the regression analysis, we will offer some descriptive discussion of the variables of interest in our database.

According to Table 2.1 public infrastructure (measured by per capita highway expenditures) has remained steadily with an average of 269 usd while private infrastructure (given by non-residential spending) accounting one-third approximately during 1993-2015 period. However, when comparing year-to-year public investments tend to be absorbed disproportionally more in bigger states (see, for example Figure 2.2). For what concerns employment rates and real wages in both top and bottom value-added high-tech sectors, results are diametrically opposed. In spite of a higher response of employment and wages —other things equal— in top value-added sectors with respect to bottom value ones; firms with a smaller contribution in terms of value share seem to provide more employment opportunities (i.e., longer intervals) and better salaries relative to more innovative sectors (see, for instance Figures 2.5 and 2.6). Therefore, longer unemployment rates couple with lower wage growth rates due a fall in labor market fluidity (Davis and Haltiwanger, 2014). Another plausible explanation, as we will show later in our wage decomposition is a higher (though) heterogeneous response of conditional wages from high-tech workers in bottom value-added sectors. Furthermore, one of the novelties of this study is the inclusion of non-monetary incentives. From Table 2.1, our reduced policy average score is 0.047 with a maximum of 0.175 whereas our modified average user cost 1.144 which is not that far from the existing literature (Moretti and Wilson, 2014).

For what concerns innovation, Figures 2.3 and 2.4 show an uneven distribution of the aggregate value share as well as the production of innovation outcomes within high-tech sectors. These trends are driven by computer & electronic product manufacturing, publishing industries, telecommunications and professional scientific and technical services accounting more than 80% of patents with respect to other sectors and the same time the former delivering higher returns to the economy in terms of aggregate value. In addition, Figures 2.7 and 2.8 show that the average patents per 100,000 population at the 90^{th} and 75^{th} percentiles were 14 and 8 respectively whilst only 2.8 and 2.9 for the lowest percentiles 10^{th} and 25^{th} respectively. Interestingly, in Figures 2.9 and 2.10, a positive relationship between market power and the innovation gap is observed.[23] Simply put, the higher the knowledge gap (i.e., the difference between top and bottom percentiles), the lower will be the market competition because most innovative firms are more likely to absorb additional resources from generous R&D tax credits which ultimately provided them additional user cost saving effects as we will show below. Or else, as concentration rise, the aggregate value share reported by high-tech industries diminishes. We offer three possible explanations: i) knowledge is more concentrated in people; ii) innovation diffusion decreases with effort but the marginal return of new patents is more profitable in sectors with lower marginal costs and value share and iii) there is a higher dispersion on productivity (see, for example Akcigit and Ates, 2019*a*,*b*). Overall, this fact implies that the gap between these two groups has been widening-up especially after 1995 (see Figure A.1.1 and Figure A.1.2 in the Appendix).

To conclude, Table 2.2 shows the correlations between infrastructure, non-monetary incentives and conditional percentiles of innovation outcomes (i.e. patents and scientific citations) for each U.S census division. In panel A, a puzzling relation between infrastructure (public and private) and employment is observed. In the first case, highway expenditures seem to have a negative (but insignificant) impact in almost all divisions for top value-added industries but not for bottom ones (three out of nine were highly negative and significant). Conversely, there is a positive and significant correlation between non-residential spending and employment growth in New England, South Atlantic, Mountain and Pacific divisions. In regards to the diffusion of past public policies in several fields (third column), correlations are mixed but mostly positive rather than negative which could indicate that delayed effects over labor markets are more likely to occur. Conversely, in Panel B there is a positive and significant correlation between wages and non-monetary incentives in almost all divisions and again mixed correlations for both types of infrastructure expenditures. Although for the entire economy correlations are mostly positive for that reason we hypothesize ambiguous effects over high-tech wages. Finally, panels C and D show the correlations between wages and the (conditional) percentiles of technological patents and scientific citations. To our surprise, both high-tech sectors seem to take advantage of public infrastructure investments for almost all percentiles while private infrastructure is not significant at all. In addition, the policy score is negatively correlated at the tails of innovation distribution but positive between the 25^{th} and 75^{th} percentiles. A possible explanation is that

[23] As firms gain market power, labor share decreases; thus employment rates tend to be sluggish. This results in a higher dispersion on markups and a decrease on the output; thereby real wages will follow that trend because prices rise as well.

new ideas grow at a decreasing rate as innovation inputs have diminishing marginal returns (e.g., the value of creating new ideas is negatively related to time and scientists effort). Hence, regardless of their diffusion pace, the marginal contribution to labor markets of each new patent has less value in terms of aggregate knowledge. Certainly, these results do not imply that (future) benefits of new innovations will be passed-through to top value-added high-tech workers. The reason is that taxation effects among top innovators are heterogeneous. As a result, regardless the type of State incentives implemented by policymakers, highly qualified workers may inevitably abandon firms in the search of more profitable opportunities (the so-called “business stealing” effect). Nevertheless, we cannot attribute further explanations because correlation does not imply causation. For that we require a formal econometric model, which we address below.

Empirical Strategy

To account for the effects of infrastructure, incentives and innovation outcomes over regional labor markets for a specific group of industries (high-tech), this paper tests two well-defined and complementary hypothesis:

H_1 : *Infrastructure expenditures (public and private) as well as incentives: monetary (R&D tax-credits) and non-monetary (i.e., the mere diffusion of a policy) can be regarded as innovation boosters (e.g., a higher share of patents and scientific citations) for regional labor markets in terms of higher employment rates.*

H_2 : *The innovation gap (i.e., the difference between top and bottom percentiles) displayed by high-tech firms in terms of aggregate value share may be the result of an heterogeneous impact into the entire (conditional) wage distribution as public policies like infrastructure and innovation activities, depend on several and possibly opposed channels within each region (e.g., the proportion of high-school and college graduates, state minimum wage changes with respect to federal ones, etc).*

2.3.3 Identification Strategy

Given that highway capital outlays (X) are endogenous, it is most likely that errors can be correlated to our dependent variable. As a result, an exogenous instrument is required. Basically, the idea of an IV strategy is appealing: i.e., to use a variation in a third variable, Z (the instrument) that is exogenous (uncorrelated) with respect to the confounding variable, but at the same time correlated with X. Nonetheless, before considering any variable as a suitable candidate, two necessary conditions must be fulfilled: Relevance and Exogeneity. Put differently, the instrument needs to be relevant and foremost, it must be exogenous meaning that it affects the outcome variable only through the instrumented variable. Alternatively, the dependent variable is weakly affected by the potential instrument(s).

In empirical grounds, the relevance is usually assessed statistically thorough the Kleibergen-Paap F-stat statistic of first stage results. However, the endogenetity analysis must be complemented with other standard tests like the Hansen J-test (overidentifying restrictions), Anderson & Rubin (AR) statistic and the C test (orthogonality condition of instruments). As usual, rejection of the first test indicates the presence of weak instruments: the Kleibergen-Paap F-stat rule of thumb (for one endogenous regressor) suggests that its value should be above the threshold of 10. Conversely, the AR test can be decomposed into the K statistic and J-statistic, where the K statistic test if the exogeneity conditions are satisfied and the J statistic. However, the J statistics is evaluated at the null hypothesis that all instruments are exogenous as opposed to the J statistic from a GMM estimation, which is evaluated at the parameter estimate. Hence, the AR test provides more information about the exogeneity of instruments. At last, the orthogonality condition given by the C test shows that a subset of selected instruments are strictly exogenous. If rejection takes place, then, instruments may be weak.

In our case, we follow the path taken by Aghion et al. (2009), Aghion et al. (2019) and we will regard as an exogenous variation in infrastructure spending the number of senators and representatives in the appropriation committee (Stewart and Nelson, 2005, Stewart III and Woon, 2017). As those studies claim, the number of committee members in the Senate is a powerful instrument for education expenditures and innovation. Even though the goal of above mentioned papers were the relation between education-growth and innovation-inequality, there is substantial evidence that it can be a useful (exogenous) and powerful instrument in regards to other state shocks like infrastructure expenditures (see, for example, Cohen et al. (2011) and Hooper et al., 2018).

In fact, unlike more specific committees like transportation, appropriation committees not only have more explanatory power (its size is more than double with respect to transportation), but above all, only the appropriation committee of senators can authorize or grant additional funds to previously approved projects. As a result, in order to provide a more flexible approach, we recode the number of senators in the appropriation committee using the following classification: 0 if the State has no representatives, 1 with at least one representative, 2 if the State has two members, 3 if the State has at least three or more representatives.

Conversely, a different road-map would be to consider a projection-growth or a shift-share "Bartik instrument" reflecting the federal origin of spending funds excluding the region under consideration (Bartik, 1991). In plain words, an interaction between a time-varying shock (the shift: in this case real highway spending) and a cross-sectional sensitivity to the shock (the share of spending outside the state under consideration). In that vein, a new strand literature explores the potential benefits and drawbacks of this approach (see, for example, Goldsmith-Pinkham et al. (2018) and Borusyak et al., 2018).

Evidently, a large body of empirical papers still regard the "shift-share" approach as a valid strategy in the presence of endogenous regressors. Nonetheless, it may not be sufficient to ameliorate the endogeneity issue and it could even lead to the spurious regression problem. Indeed, interacting a time-series variable with another variable that varies only in the cross section provides flexibility but this comes at a cost, especially in the presence of common time-trends and/or shocks. What is more, placing higher weights on a particular sectors (e.g., nontradable vs tradable) may worsen both relevance and exacerbate the potential endogeneity (Broxterman and Larson, 2020) through a higher correlation structure between the errors and the shift-share instrument.

Accordingly, our empirical estimates relies on the committee members in the Senate as an exogenous variation of highway expenditures. As for the lag structure of the exogenous regressors, we follow the strategy applied by earlier studies Aghion et al. (2009), Aghion et al. (2019) and use a maximum of two lags. Yet, given that it takes time to a new member to affect highway outlays, we augment the number of lags of the endogenous variable up to 5. The latter is consistent with the fact that highways require maintenance, upgrading and completion based on pre-approved projects for which the senator was appointed.

2.4 Infrastructure, Incentives and Innovation

2.4.1 Employment Analysis

IV Results

H_1 : *Infrastructure expenditures (public and private) as well as incentives: monetary (R&D tax-credits) and non-monetary (i.e., the mere diffusion of a policy) can be regarded as innovation boosters (e.g., a higher share of patents and scientific citations) for regional labor markets in terms of higher employment rates.*

Before discussing the empirical results, we previously checked the stationary properties of all the variables involved in the analysis (results are available upon request). Additionally, in order to avoid the well-known spurious regression problem, we include the net GDP growth rate excluding both infrastructure measures. At last, a dummy variable equal to one for periods in which public capital outlays changed in terms of state population size is created. In this way, the stability of the panel is not compromised when Census division fixed effects are considered. It is worth stressing that we do not control for amenities like state crime rates because they are likely to be endogenous to current labor market conditions.

Tables 2.3 and 2.4, present the IV/GMM results using the above mentioned instruments for highway capital outlays. Throughout the employment analysis, I estimate models with infrastructure expenditures (public and private), incentives (monetary and non-monetary) and innovation outcomes measured by the disaggregated distribution of conditional patents in the high-tech industry with different aggregate value shares.

Columns I and II (both tables) with and without geography controls indicate the presence of a "market enabler" effect of private infrastructure over public infrastructure. That is in the short-run increase in private non-residential spending has a positive impact over employment. Point estimates in all high-tech industries and top value-added sectors are highly significant with an average value of 0.808% and 1.064% respectively. Conversely, in bottom value-added sectors results show a "disabler" and significant net effect. That is all coefficients of public infrastructure (i.e. with and without conditional patents) are negative and statistically significant with an average point estimate of -2.282% and -2.734% respectively whilst private infrastructure remains positive but statistically insignificant. Likewise, a policy diffusion score of past public policies has a positive and significant effect over total high-tech employment and top value-added sectors. For instance, a 1% increase in the policy score leads to an increase of 0.895% in employment for the top value added firms and 0.804% for the total industry other things equal. When innovation outcomes are considered, an inverted and significant u-shape is observed for all high-tech industries. Interestingly, these elasticities are driven by lower value-added sectors rather than top ones which remain insignificant with and without geography controls. As existing evidence on the U.S business slowdown documents, a possible explanation of these results can be the decreasing and/or stagnant aggregate value shares in sectors with higher marginal costs or more prone to experience higher labor turnover rates. In this way, the return of new ideas in sectors with lower value-added shares outperforms those with more aggregate value for the economy.

Moving further to column III, the "market enabler" effect with and without innovation outcomes vanishes as additional controls are included. That is point estimates continue to be positive and significant but the net effect of public infrastructure is stronger. Thus, the "disabler" net effect offsets the private market price effect regardless the group under consideration.

Policy diffusion coefficients are slightly lower but continue to be positive and significant for the aggregate and top value-added high-tech sectors with the exception of bottom-value added which remain positive but statistically insignificant. For what concerns monetary incentives, more generous R&D tax credits offered by states, imply a positive and significant response on high-tech employment of 27.736% and 61.375% in top and bottom value-added sectors respectively for a three year (cumulative) window. Likewise, when conditional innovations are included the same trend is observed although point estimates in top value-added sectors cease to be significant. Along the same monetary lines, the R&D user cost shows that a 1% reduction is associated to a (15.769%) 21.681% employment increase in bottom value-added industries when innovation outcomes are (excluded) included, which is more than twice the amount of cost saving effects in top value-added sectors (-7.155%) and -10.935% respectively. When interactions between R&D tax-credits and firms user cost are considered, the difference between bottom and top value-added sectors remains significantly higher. That is point estimates of the interaction variable in high-tech sectors with lower value share are associated to a 17.889% of employment growth while in top sectors is less than half (-8.166%).

Accordingly, our evidence shows that larger amounts of knowledge in most-innovative sectors do not necessarily imply a higher contribution to employment rates for the aggregate economy. Expressed differently, the marginal return of a new patent and/or a scientific citation in the bottom value-added group has more value than the same innovation performed in the top value-added sector. Overall, the statistical performance of our instruments is acceptable given that both the overidentification and orthogonality tests (i.e., Hansen J-test and C-statistic) are not rejected at any significance level. This is also confirmed by the joint test of the structural parameters and the exogeneity of the instruments (AR test). In this case, the J statistic is evaluated at the null hypothesis as opposed to the Hansen J statistic from the GMM estimation, which is evaluated at the parameter estimate. Here rejection (at 10% level) takes place only in models without full controls and 5% to 10% when conditional patents are considered with full controls. In the remainder cases, the null hypothesis of weak instruments is above the 10% rejection interval. Nonetheless, caution must be taken with the latter results as they could be compromised by weak and strong cross-correlation an issue that we address below.

Robustness Checks

Instrumental Variable With Arbitrary Clustering

An important issue within panel data models that needs special care is serial correlation. In this vein, estimates can either be positively (negatively) correlated to the unobserved component of the dependent variable and/or with state-specific shocks among units and time (i.e., multiclustering). Moreover, persistence is likely to occur even in the absence of endogeneity; thereby, an adequate treatment of these problems is mandatory.

In empirical grounds, modelling the error term within a spatial framework provides a feasible strategy to tackle both issues. However, assuming a functional form of the error term may come with costs as multiway clustering implicitly regard a regularity condition. Simply put, each entry of the spatial matrix must share at least one dimension of clustering. This stringent but sufficient condition, means that both observations (in space and time) should be correlated with the error term and thus; they must also be dependent at time s. Unfortunately, in many real-life settings, this particular clustering structure does not hold.

Accordingly, an arbitrary cluster setting offers a more flexible approach since it allows units to be correlated with each other in any possible way, without any kind of imposed structure. What is more, regardless the data structure, not only it accounts cross section dependence and time dependence, but also interactions between the two dimensions as well. In this manner, spatial changes can be captured over time or in any kind of decay between two moments in time t and s.

Formally, the researcher observes each individual (i) several times in different periods (t). As usual, y is the dependent variable and the objective is to obtain within estimates. Then, following Colella et al. (2019), the sandwich formula of the variance/covariance for OLS is defined as:

$$\widehat{VCV}(b_{ols}) = (X'X)^{-1}X'(S\ x\ (ee'))X(X'X)^{-1} \tag{2.4}$$

where e represent the residuals ($e \equiv\ y\ - Xb_{ols}$) and S is the matrix of dependence (clusters) between residuals.

The same strategy from above could also be used in the presence of endogeneity.[24] Considering the linear two-stage least squares case with more instruments than endogenous regressors,

[24]In the case of a shift-share analysis where the residuals between observations with similar distributions (of the shares) are correlated, this strategy would also be valid. Indeed, one would have to compute a similitude index between each pair of states based on a set of weights of the shift-share instrument(s) which yields a distance matrix S; and after that one could use S for arbitrary clustering. This refinement may alleviate a common problem of the shift-share empirical literature which is the relevance condition of an instrument with a higher weight.

the variance/covariance matrix changes to

$$\widehat{VCV}(b_{2SLS}) = (\hat{X}'\hat{X})^{-1}\hat{X}'(S\ x\ (ee'))X(X'X)^{-1} \tag{2.5}$$

where u represent the residuals ($u \equiv\ y\ - Xb_{2SLS}$) and again S is the matrix of dependence (clusters) between residuals.

In broader terms, arbitrary correlation conveys that each observation's error term at a particular point in time may depend on other observation's error terms with a certain strength. All this information is collected in a matrix called (S). In the spatial context, S is normally built from information on the geographic distance between spatial units (e.g., latitude and longitude between regions, cities, and countries).

It is worth stressing that unlike conventional inference —which leads to inconsistent estimates of the variance-covariance (VCV) matrix—, the performance rate in terms of rejection rates for small samples in arbitrary clustering frameworks is approximately 10% and converges quickly to the true significance level of 5% as the sample size increases. Therefore, this suggests that the latter correction produces consistent estimates of the VCV with respect to the former one. Thus, enabling applied econometricians to conduct robust inference in the presence of spatial correlation.

For what concerns our first research question, an instrumental arbitrary correlation framework is more suitable to account for different shocks like infrastructure expenditures, innovation outcomes and/or outliers. For instance, in the case of "star scientists" it is likely that contiguous states are affected by common shocks (e.g., tax-credits) and this should be reflected in the clustering structure. In the case of policy diffusion, clustering could be at work in first adopters and/or bordering states (e.g., tax and expenditure limits (spending limits): first year applied 1976; last year applied 1994). However, given that each state has its own tax legislation, and the results of such policies are publicly available, correlation among units will tend to decay over time. For the same token, the IV-AC is also robust to cases where public investments tend to be absorbed disproportionally more (i.e., bigger states) and at the same time, in states where there is an uneven number of representatives (i.e., senators) in the appropriation committee or innovation clusters.

IV Arbitrary Clustering Results

Tables 2.5 and 2.6 show the results of equation 2.3 accounting for an arbitrary clustering spatial framework. Columns I and II (both specifications) with and without geographical controls confirm that the "market enabler" effect of private infrastructure over public infrastructure still holds in all high-tech and top value-added sectors. That is point estimates are positive and highly significant. Likewise, in bottom value-added firms results confirm that the "disabler" effect of public infrastructure is still operating as coefficients of highway spending are negative and statistically significant. A policy diffusion score of past public policies has a positive and significant effect over total high-tech employment and top value-added but insignificant in sectors with lower value share. Interestingly, the upper part of the conditional distribution of innovations (i.e. patents) in top value-added sectors are statistically significant while in bottom value-added sectors the inverted u-shape effect weakness.

Accordingly, thus far the use an arbitrary clustering correlation with and without geographical controls delivers results which are quantitatively similar with respect to those in the previous section. Nonetheless, when more controls are included (column III), the "market enabler" effect without innovation outcomes vanishes (i.e. coefficients are no longer significant) and point estimates of public infrastructure are considerably lower in magnitudes and insignificant (-0.107 and -0.285) in all high-tech and top value-added sectors respectively. Conversely, when conditional percentiles of technological patents are considered private infrastructure is highly significant and offsets the negative effect of highway spending and the inverted u-shape relationship previously identified remains stronger for firms belonging to lower value share group rather than top value-added ones.

We offer two possible explanations for these new results: 1) the presence of "direct" networking effects of public policies. For example, a 1% increase in the the policy score implies a 0.793% employment growth for firms in top value-added sectors. Yet, the same argument does not hold for bottom value-added sectors given that point estimates continue to be positive but mostly insignificant. 2) increasing returns of monetary incentives and cost-saving coupled with "indirect" effects of State of past policies. For instance, entries in column III suggests that more generous R&D tax credits offered by states, imply a positive and remarkably different response on employment growth of 54.448% (85.034%) and 28.841% (27.184%) in bottom and top value-added sectors with and without innovation outcomes. Likewise, R&D user cost as well as interactions with generous tax-credit remain statistically significant and have the expected signs. Evidently, spatial interaction effects cannot be disregarded as these may explain why public policies like infrastructure expenditures and innovation policies are more effective in firms with different aggregate value shares.

In light of these new evidence some points are worth mentioning. First, the inclusion of incentives (monetary and non-monetary) coupled with infrastructure expenditures (public and private) and innovation outcomes (i.e. technological patents) must be considered "boosters" for other regional economies. In other words, cross-sectional dependence (CSD) is expected to be present in the analysis. For that reason, a weighted CSD test (CD_W) while accounting for serial correlation was employed (Juodis and Reese, 2021). Results show that the null hypothesis of (weak) CSD against strong one is rejected at 5% in GMM/HAC for all high-tech sectors whereas in the IV clustering framework the p-values of the CD_W are well-above the 10% rejection. Therefore, spatial effects and common factors play an important role in our analysis and these must be taken into account. Second, to have a qualitative response of how infrastructure, incentives and innovation outcomes impact high-tech workers, a wage decomposition is analysis necessary. We explore that venue in section 2.4.2. Third, interaction effects between spatial variables, incentives (monetary and non-monetary) and innovation outcomes may capture not only spillover effects but also agglomeration economies. To this end, below we apply filtering techniques and then check for the presence of CSD on the residuals of the Spatial Lag Model (SLX) while accounting for endogeneity.

Direct, Spillover Effects & Agglomeration Economies

In order to estimate direct and indirect effects we first test for the presence of spatial effects (Moran et al., 1993). Table 2.7 shows the results of Moran I test for a window of 5 years. As discussed earlier, we consider a window of five years because infrastructure investments are mostly slack and it takes time to unpack its cumulative effects. After confirming the presence of "local" spatial relations we estimate a SLX model. These type of models can be considered as a point of departure due to its flexibility in regards to direct and local spillover effects (see, for example Gibbons and Overman (2012), LeSage and Pace (2009), Halleck Vega and Elhorst (2015) and Elhorst (2021) among others).

Table 2.8 presents the results using the first-difference Bai-Ng filtering method. At first sight, after accounting for common effects, we obtain a lower CD statistic. That is p-values are well-above the 10% and with only one specification close to 9% rejection rate. Hence, we cannot reject the null of weak CSD hypothesis against strong one. Thus, estimates do not suffer from spurious inference problem. Furthermore, our SLX model includes interactions between exogenous regressors and spatial lag variables. These new variables capture not only indirect effects and/or agglomeration economies, but also account the spatial endogeneity. It is worth mentioning that we do not instrument spatial lagged variables. The reason is spillovers effects generate an obvious violation of the exclusion restriction. That is if other predictor(s) values directly affect the outcome they cannot be valid instruments. In the case of a public goods like infrastructure the inclusion of past predictors of the spatial variable produce a tension because the other spatial relationships must be rule out simultaneously. That is units should not be benefited from these investments which is an unrealistic assumption. Moreover, if the spatial instrument is exogenous it would imply that there are no simultaneous relationships (between units) involved in the analysis both in the first and second stage analysis. Accordingly, an instrumentation of the spatial lag variable should be avoided as it constitutes a violation to the system of equations given that variation comes from within and not from the outside.

The SLX results show that direct effects of public infrastructure are positive and significant at 10% level. That is coefficients rang from 0.129 to 0.154 indicating that after 8 years highway expenditures increase high-tech employment. Surprisingly, private infrastructure measured by non-residential spending is insignificant or most probably positive effects are located for more disaggregated units (e.g., counties). In regards to innovation, both sectors top and bottom value-added show a positive significant response. Particularly, a priori one would expect that firms with a higher aggregate value share would contribute more to high-tech employment than those with lower value. However, when spatial factors are accounted for point estimates are both positive and significant but remarkably close each other: 0.616 and 0.510 respectively. This fact confirms my previous findings that is the return of new ideas is more profitable in sectors where marginal costs are already lower.

Last but not least, I find no evidence of public infrastructure spillovers when local revenues for roads, streets, and highways increase. This fact can be explained by a higher presence of representatives in the appropriation committee. Expressed differently, one would expect that states with more senators may influence the budget to increase the performance not only on high-tech industries but also in other traditional industries (like construction) as well. But, as explained earlier infrastructure expenditures under the ARRA were modest or close to zero where only six jobs were created per $1 million usd (Garin, 2019).

Interestingly, interactions between non-monetary incentives (i.e. the diffusion of past policies) and innovation outcomes in both sectors are both positive (0.183 and 0.152 respectively) but only significant in sectors whose aggregate value share is larger. That is networking effects of ideas are transferred to other states provided that firms stimulate their local economies by increasing rates of ideas (i.e. production of technological patents) due to generous tax-credits. This is an important contribution of my paper because it links the effectiveness of past public policies, innovation outcomes and labor market performance in sectors where agglomeration economies and externalities are considerably larger with respect to construction industries usually associated to these investments.

Finally, I test for the presence of indirect effects of tax-credits through innovations (i.e.

patents) in both sectors and firms' user cost. Compared to the existing evidence (see, for example Moretti and Wilson, 2014), I find positive and significant spillover effects over total high-tech employment. For instance, when interactions between R&D user costs technological patents in bottom value-added sectors are considered, the effect of generous subsidies is 0.431 and significant while in sectors with higher aggregate value share the effect is slightly lower (0.424) and also statistically significant. This is an important departure from the "beggar the neighbour effect" (see, for instance Wilson, 2009) because infrastructure investments couple with incentives both (monetary and non-monetary) indirectly generate positive spillover effects in other high-tech industries and foremost curbs inventors incentives to move out from their regions. For those reasons, the evidence on this paper supports the effectiveness of "jobs to people" policies in regards to business dynamism for regional economies.

2.4.2 Wage Analysis

Quantile Wage Decomposition

Extant literature of road infrastructure has applied quantile methods in the past but with a focus on poverty (Khandker and Koolwal, 2010, 2011). To be precise, the aforementioned studies employ a correlated random component as an additional covariate in their models to account for unobserved heterogeneity amongst units. However, a problem with this approach is that including control variables in a quantile regression model alters its interpretation for a specific individual with and without a predetermined characteristic.

To empirically address our second question, the within-transformation could be used to wipe out all the effects across variables before applying OLS. Unfortunately, this strategy fails to uncover unobserved heterogeneity and above all, its bias will be related to the unobserved component of model. That is the τ^{th} quantile for a particular state with lets say better infrastructure services and/or with more innovation clusters is not the same as the τ^{th} quantile for another one with lower quality and/or lower quantity of patents per state. Another alternative is to simply take the pooled averages of the population i.e., averaging the individual-level effect across units. But, in this case the average (marginal) effect will be constant as we assume that the model is linear on its parameters; thereby, we will not be able to capture the unobserved heterogeneity.

Accordingly, from an empirical point of view there is substantial evidence that the use of quantile regression models overcomes both problems and above all it is robust to the presence of outliers. Nonetheless, as in any scientific subject, not every problem can be addressed with the same recipe. In other words, there are several quantile estimators which make use of different assumptions to recover the parameters of interest and at the same time exploit the conditional heterogeneity among units.

Following the previous line, the simplest approach would be a linear (additive fixed effect) estimator which appropriately takes care of the unobserved heterogeneity. In this line, as Canay (2011) suggests, the problem is sequential. In the first step, all the individual effects are estimated by using the standard (within) fixed effects estimator for linear panel data. Later in a second step, the recovered coefficients are estimated by standard quantile regressions (i.e., treating the estimated individual effects from the first stage as given). Overall, the intuition behind this procedure is straightforward because the researcher assumes that the parameters will remain unchanged.

Nonetheless, the procedure from above is not exempt from drawbacks. On the one side, as Chen and Huo (2019) points out, simplicity comes at costs. First, the two-step procedure requires certain moments of the idiosyncratic errors to exist, and thus the robustness of quantile regressions against heavy-tailed distributions must be sacrificed. Second, the assumption that $N/T^s \to 0$ for some $s > 1$ is not enough to ignore the asymptotic bias of the estimated coefficients. For example, according to their simulations, coverage rates of the confidence intervals (with 95% nominal levels) based on this type of estimator are lower than 1% when N = 1,000 and T = 20 which are not that far from our data structure (N=1,300 and T=26). In addition, the asymptotic variance of the Canay estimator for the constant term is not correct. To this end, the authors suggest a smooth quantile regression (SQR) instead of the quantile regression to estimate the coefficient of the regressors while preserving the first stage fixed-effect estimates. In this way, coverage rates of the confidence intervals are improved once the analytical variance correction is done; thereby providing a valid inference of the estimates.

On the other side, in the context of a continuous (non-discrete) endogenous regressor like highway capital outlays, if the dependent variable and/or its lags are correlated with the variable being instrumented, then, the IV moment condition considered in the approach of (Chernozhukov and Hansen, 2008) may not be appropriate. Likewise, under the presence of individual factors correlated with the independent variable(s), one could apply the estimator suggested by Harding and Lamarche (2009). Their quantile estimator allows the endogenous variable to be correlated with unobserved factors affecting the conditional response variable. In this way, the researcher can estimate the covariate effects at different points of the distribution while controlling for individual heterogeneity.

Certainly, the estimators from above have their own benefits and pitfalls because including a set of dummy variables representing each cross-sectional unit could create an incidental parameter problem affecting the consistent estimation of all coefficients in the model (further details are discussed in Koenker (2004), Powell (2016) among others). Moreover, since fixed effects are additive we cannot make interpretations at an individual level. Although, we might report the "average" conditional quantile effect across the whole population as representative effects assuming that the parameters of interest do not vary based on the fixed effects (in the spirit of Canay two-step estimator).

Consequently, for our wage decomposition model we proceed with the quantile panel estimator with nonadditive fixed effects proposed by Powell (2016). The intuition and simplicity of this estimator makes the computational analysis less burdensome. In plain words, it assumes that the parameters of interest vary based on the nonadditive disturbance term while maintaining the nonseparable disturbance property of the basic quantile regression model which is the backbone of quantile regression models. Yet, there are two major concerns that must be taken into account.

First, the existence of large number of fixed effects to be estimated and second; the incidental parameters problem when the dimension of the panel is relatively small. In broader terms, the estimator from above overcomes both issues to our data generating process; thereby each regressor can be recovered if there is enough variability within each iteration (below we will briefly outline its intuition).

To motivate further our empirical application for high-tech industries, we follow the notation of Powell (2016). From an empirical point of view, our wage decomposition aims to shed some light on the tech/non-tech puzzle found by Kemeny and Osman (2018). However, in our case we hinge upon the empirical regularities of U.S public firms for which different aggregate value shares and hypothesize that such puzzle may be the result of a set of past public policies like infrastructure expenditures and incentives (monetary and non-monetary) that could have affected the conditional distribution of wages in (within) high-tech sectors.

Formally, our model can be specified as follows

$$y_{it} = D_{it}\mu`(U_{it}^{*}) \quad U_{it}^{*}\, U(0,1) \tag{2.6}$$

where y_{it} is the outcome variable which is log annual payroll of high-tech industries (top and bottom value-added per 100,000 population); $D_{it} = (I_{it}, X_{it})$ is a vector of treatment variables for each state i at time t. In addition, we include a set dummy variables like Census divisions, recessions, state minimum wage changes with respect federal ones, time effects (e.g., decades to capture cumulated effects) as well as our monetary and non monetary incentives (i.e., infrastructure, the diffusion of policies and innovation outcomes) along with the usual controls from the urban economics literature. It is worth stressing that U^*_{it} is general disturbance term which may be a function of several disturbances. Since it is uniformly distributed, we can say that it represents "proness" for the outcome variable. Therefore, we can express it as an unknown function of individual fixed effect (αi) and the observation specific disturbance term U_{it} as follows

$$U^*_{it} = f(\alpha i, U^*_{it}) \quad where \quad U_{it} \sim U(0,1) \tag{2.7}$$

With respect to traditional quantile methods which assume independence between U^* and D, the nonadditive fixed effect estimator does not specify nor estimates the individual fixed effects. Accordingly, the number of parameters to be estimated is relatively small of other estimators like Canay (2011).

In practical terms, the implementation of the nonadditive estimator has two important advantages with respect to the quantile fixed-effect estimator. First, it provides the estimates of the conditional distribution of $yit|D$ which can be interpreted with the usual standard inference tools as in many empirical applications. Second, given that fixed effects quantile regression estimates are in general biased and inconsistent when the time dimension of the panel is small and fixed (the so-called incidental parameter problem), once identification is achieved, the nonadditive quantile panel estimates are consistent, have an asymptotic normality and foremost they provide an adequate inference (Powell, 2016). Furthermore, even with a short time span (e.g., T=2) the estimator still has a good performance.

Finally, it is worth mentioning that direct comparisons between both quantile specifications (with and without additive fixed effects) should be made with caution because the latter is estimated through the Markov Chain Monte Carlo (MCMC) optimization method which is sensitive to the order of the regressors as well as the acceptance rate of the algorithm implemented. Also, the casual inference of the estimates with additive fixed effects is completely different.

Normality test for panel data models

From an empirical point of view, there are two ways to check for the normality assumption. On the one hand, one could use a quantile-quantile plot (Q-Q plot) to have a quick glimpse of the DGP. Indeed, if the variable(s) are normally distributed, then, the scatter diagram(s) should be on the diagonal line. Rejection takes place when diagrams for each Q-Q plot deviate from the diagonal lines. Another interesting and (practical) approach is to visually assess the skewness and kurtosis of the variable(s) of interest. In our case, we adopt a two-step procedure and first visually evaluate normality by focusing on pairs of relations between wages, innovation and infrastructure. For the sake of the space, we refer the reader to Figures 2.11, 2.12, 2.13 and 2.14. Overall, results from the analysis show fatter (skewed) tails by decades and divisions.

In a second step, we adopt a formal test to check whether quantile methods are suitable. In plain words, normality is tested separately and jointly through the innovation and specific error terms (Galvao et al., 2013). More precisely, the test controls for normality within the panel structure by assessing skewness and kurtosis. Overall, rejection of the null hypothesis would indicate that the error structure does not follow a normal distribution. Hence, the linear regression model (LR) based on the conditional mean estimation would not be able to account for the unobserved heterogeneity. At last, disregarding this valuable information in terms of deviations from (a)symmetry and/or excess of kurtosis may cast doubt on the empirical estimates. For the sake of simplicity, we will use the same notation employed by the authors to briefly summarize the intuition of both tests. Consider the standard panel data model with one-way error-components model as the following:

$$y_{it} = \alpha_0 + \beta_0 x_{it} + u_i + e_{it}, \quad i = 1, ..., N, \quad t = 1, ..., T \tag{2.8}$$

where α_0 is a constant; β_0 is a p-vector of parameters; u_i and e_{it} refer to the individual-specific and the remainder error component, respectively (both which mean zero). As usual, the subscript i refers to individual, and t refers to time. Then, the separate skewness and kurtosis in the u_i and e_{it} are calculated as follows:

$$Skewness = \begin{cases} s_u = \frac{\mu_3}{\sigma_\mu^3} = \frac{E[\mu^3]}{(E[\mu^2])^{3/2}} \\ s_e = \frac{e_3}{\sigma_e^3} = \frac{E[e^3]}{(E[e]^2)^{3/2}} \end{cases}$$

and

$$Kurtosis = \begin{cases} k_u = \frac{\mu_4}{\sigma_\mu^4} = \frac{E[\mu^4]}{(E[\mu^2])^2} \\ k_e = \frac{e_4}{\sigma_e^4} = \frac{E[e^4]}{(E[e^2])^2} \end{cases}$$

To test the normality of y_{it}, the following separated (1 and 2) and joint (3) hypothesis are considered:

(1) Skewness: $H^{s_u} : s_u = 0$ and $H^{s_e} : s_e = 0$

(2) Kurtosis: $H^{k_u} : k_u = 3$ and $H^{k_e} : k_e = 3$

(3) Joint: H^{s_u,k_u} : $s_u = 0$ and $k_u = 3$ and H^{s_e,k_e} : $s_e = 0$ and $k_e = 3$

Overall, rejection of the null hypothesis would indicate that the error structure does not follow a normal distribution. Hence, the linear regression model (LR) based on the conditional mean estimation would not be able to account for the unobserved heterogeneity. At last, disregarding this valuable information in terms of deviations from (a)symmetry and/or excess of kurtosis may cast doubt on the empirical estimates.

Normality Test Results

We perform the analysis for our two high-tech sectors using the same controls from the employment models but including dummies by regions and decades. Results in Table 2.9 confirm that the null hypotheses of the 6 indices are rejected. Indeed, skewness is highly significant in both error terms (innovation and state) whereas individual kurtosis is significant at a 10% in bottom value-added sectors. Nonetheless, both joint hypothesis are rejected at 1% and 5% level respectively. Therefore, based on these results, we conclude that wage distributions in both groups (top value and bottom value-added) are asymmetric and left-skewed.

Overall, both strategies (a visual inspection and a formal test) imply that our sample data is not normally distributed. Consequently, OLS methods are not appropriate to investigate the effect of infrastructure and innovation policies over high-tech wages. Therefore, the panel quantile regression with nonadditive fixed effects is more appropriate for our wage decomposition. Notwithstanding the clear differences between conditional mean regressions and quantile panel data models, we will compare their performance to double-check our results. Nonetheless, caution must be taken because the latter is estimated through the Markov Chain Monte Carlo (MCMC) optimization method which is sensitive to the order of the regressors.

Interestingly, another striking difference of the above mentioned framework with respect to standard quantile models (i.e. with additive effects) is the casual inference of their estimates. In the second case, the interpretation is completely different because it separates the disturbance term into different components and assumes that the parameters vary based solely on the time-varying components of the error term. Put differently, it alters the interpretation of the parameters of interest relative to cross-sectional quantile regression (QR). Hence, if non-separability holds, then, the resulting estimates can be interpreted in the same spirit as cross-sectional quantile estimates (i.e., what would be the impact on the quantile τ^{th} due to a change on the explanatory variable). For all those reasons, our empirical estimation implements the instrumental quantile estimator with nonadditive fixed effects.

Quantile Wage Decomposition Results

H_2 : *The innovation gap (i.e., the difference between top and bottom percentiles) displayed by high-tech firms in terms of aggregate value share may be the result of an heterogeneous impact into the entire (conditional) wage distribution as public policies like infrastructure and innovation activities, depend on several and possibly opposed channels within each region (e.g., the proportion of high-school and college graduates, state minimum wage changes with respect to federal ones, etc).*

In lieu with the empirical wage literature, we measure the dependent variable in log values and normalized its value by state population to control for business cycle effects. As a first step, we examine the performance of the quantile estimator with nonadditive effects by running a simple model without controls. More precisely, we include both measures of infrastructure (public and private), non-monetary incentives (i.e. a policy score) and conditional patents controlling only for dummies (U.S Census division and decades). As explained, these effects will be separated from the main covariates, providing us a clean inference. Again, we check for normality applying the above mentioned test. Results (see, Table A.4.3) show that the null hypothesis of 6 indices for top value-added sectors and 5 in bottom value-added ones are rejected. Hence, wages from high-tech workers are asymmetric and left-skewed.

In Figure 2.15 we provide the marginal effects of our benchmark specification for the most important quantiles. At first sight, the "disabler effect" of highway spending is also at work regardless the group under consideration. Indeed, in top and bottom value-added groups the negative impact decreases throughout quantiles. Not surprisingly, the market price effect of non-residential private expenditures is positive and highly significant at the 50^{th} quantile and beyond the median for both sectors. In plain words, private infrastructure ameliorates the negative initial impact of public investments of workers located in the median and above the 75^{th} and 90^{th} quantiles in bottom value-added sectors. For what concerns innovation, results are mixed: A higher number of high-tech patents is associated to better salaries in both sectors throughout quantiles. In line with empirical evidence (see, for example, Moretti and Wilson, 2014), top earners seldom enjoy the full benefits of their own scientific contributions. For instance, a 1% increase in technological patents workers leas to a 0.075% and 0.096% in wages for both top and bottom value-added sectors respectively. Lastly, a higher policy score is positively associated o higher wages in top value-added sectors while in bottom value-added the relationship is mostly negative and significant with the exception of top earners. Nonetheless, as we will show later, these results do not prevent that workers from those industries may enjoy from better salaries due to monetary incentives provided by states (e.g., R&D tax incentives) and/or higher minimum wages with respect to federal ones. Accordingly, with respect to conditional mean estimates (not reported but available upon request), quantile models unpack significant (though heterogeneous) effects of infrastructure, non-monetary incentives and innovation outcomes across the entire (conditional) wage distribution of high-tech industries.

Moving further to a full specification, we estimate a quantile panel data model with non-additive fixed effects using the same controls employed in the employment analysis. Before discussing these results, we first check for the absence of normality for the two groups of high-tech industries. In Table 2.9 the null hypotheses of the 6 indices for top value-added sectors are rejected while 5 indices in the bottom value-added ones. Again, skewness is highly significant in both error terms (innovation and state) whereas state specific kurtosis ceased to be significant in the latter group. Nonetheless, both joint hypothesis are rejected at 1% and 5% level respectively; thereby indicating a leptokurtic distribution. Therefore, we conclude that distributions from both groups are asymmetric and left-skewed

Table 2.10 shows our main results of the wage decomposition. The negative and significant impact of public infrastructure is wiped-out after the 20^{th} quantile in top value-added sectors. Interestingly, workers located at the top side of the wage distribution (95^{th} percentile) are more likely to enjoy the benefits of highway expenditures. Evidently, quantile models are more flexible to unpack the effectiveness of these policies at different parts of the distribution with respect to conditional (mean) estimates where coefficients of public infrastructure are positive (0.025%) but statistically insignificant. Conversely, in bottom value-added sectors a sort of inverted u-shape relation is observed. For instance, a 1% increase in highway spendings is associated to a 0.189% increase in salaries for workers located in the upper side of the distribution (95^{th} quantile). Again, conditional mean models indicate a decrease though insignificant effect of 0.120% in wages. In the case of private infrastructure, for top value-added sectors there is a positive effect of non-residential spending throughout quantiles with a maximum of 0.127% at the 75^{th} quantile. Oppositely, in bottom value-added sectors private infrastructure is mostly negative and statistically significant specially at the 10^{th} quantile where point estimates indicate a decrease of -0.255% in real wages. However, as we move across the distribution, its magnitude weakens to finally become positive but insignificant i.e. 0.197% at the 95^{th} quantile.

For what concerns innovation, results results are mixed. On the one side, in top value-added sectors a higher number of technological patents and scientific citations is positively associated to better salaries. However, in the upper side of the distribution coefficients become negative and cease to be significant. Conversely, in the bottom value-added group the relationship is mostly monotonic and highly significant. Again, as in the benchmark case, a possible explanation is the presence of decreasing marginal returns in regards to new knowledge and/or displacement effects amongst top earners in sectors whose aggregate value share is higher. Conversely, in bottom value-added sectors these returns are more profitable because each new patent makes a substantial improvement to the industry in terms aggregate value share. Expressed differently, the weights of patents and wages are inversely related in top value added sectors. For those reasons, we argue that top innovators are more likely to abandon firms in the search of better opportunities (the so-called "business stealing" effect).

In regards to non-monetary incentives, a higher policy score does not necessarily imply better salaries. In top value-added sectors there is positive effect over wages but these are restricted only to the tails: 0.029% and 0.005% in the 10^{th} and 20^{th} quantiles respectively. Nonetheless, throughout quantiles point estimates start decreasing from the median onwards to finally become negative and statistically significant. Oppositely, in bottom value-added industries coefficients are mostly negative and significant suggesting that in the medium-run, the diffusion of past policies are associated to lower salaries. In that vein, two points are worth stressing. First, the fact that innovation networks may have had positive effects over employment rates does not imply that workers from those industries would have been benefited proportionally from such policies. Second, the universe of high-tech industries is composed by heterogeneous sectors with different marginal costs and technologies. Hence, it seems reasonable to expect that wages may also depend on specific job characteristics (e.g., creativity, originality, etc) as well as schooling requirements (i.e., high-school or college degree) involved in tradable and nontradable sectors like in Kemeny and Osman (2018) framework. Evidently, a comprehensive study of infrastructure expenditures considering all those aspects comes at the cost of more disaggregated relations between firms and workers. Hence, we leave that for future research.

Last but not least, we find important effects of general R&D tax-credits on wages but magnitudes cannot be compared directly to those from the existing literature (Moretti and Wilson, 2014). Naturally, one may wonder whether or not the employment benefits found in our empirical analysis were also pass-through to better salaries in industries with different aggregate value shares. In the case of top value-added sectors, our quantile results show a significant effect of 2.005% at the tails (10^{th} quantile). However, as we move across the distribution, point estimates become negative and significant e.g., -4.432% at the 95^{th} quantile (top earners). This result reinforces the fact that most qualified workers seldom enjoy the full benefits of development incentives. For bottom value-added sectors, these generous subsidies are mostly associated with higher salaries in almost all quantiles, especially at the 50^{th} quantile (4.572%).

Therefore, the median worker benefits more from R&D tax-credits and has on average a higher salary with respect to another same worker in top value-added sectors. Accordingly, monetary incentives are positively (negatively) associated to higher (lower) salaries in bottom (top) value-added industries which suggests that these generous subsidies do not always lead to higher wages. Likewise, both R&D user cost and interactions display mixed results. That is the direction of coefficients might lead to payroll reductions or increments depending on the quantile and/or sector under analysis. For example, at the tails of the wage distribution (10^{th} quantile), a 1% reduction in the R&D user cost results in a 0.609% and 2.204% increase in the average salary in top and bottom value-added sectors respectively. However, for top earners these are considerably much larger in bottom (14.779%) rather than top value-added (0.148%) sectors. Interestingly, interactions between R&D user cost and state subsidies suggest that only workers located at the 20^{th} quantile benefit from a 1.353% increase in real wages. Conversely, in top value-added sectors point estimates are mostly positive and statistically significant for top earners (e.g., 1.210%).

In light of these new results we offer two plausible explanations. First, development incentives have larger effects on firms whose marginal costs and/or aggregate value share are already lower. This would explain why top earners (i.e. those with more human capital and skills) from top value-added sectors are more likely to abandon firms in the search of more profitable opportunities and not the other way around. Unfortunately, one limitation of using aggregated data is that we cannot account the proportion of workers belonging to a top or bottom value-added sectors willing to leave the firm. Second, the presence of labor market regulations like minimum wages could be at work. To this end, we explore that venue and re-run our wage decomposition including a dummy variable equal to 1 for changes in state minimum wages with respect to federal ones. This is supported because each state is relatively an independent unit and may have a different wage legislation. Results (see, Table A.4.6 in the appendix) show a positive and significant impact over real wages in almost all quantiles. In the case of top value-added sectors, higher minimum wages with respect to federal ones imply better salaries for workers located at the 10^{th} (0.117%) quantile while for top earners the effect is moderate (0.083%) but continues to be statistically significant. For bottom value-added sectors, coefficients are larger and significant but beyond the median the magnitudes drop; and for top earners, point estimates become negative and significant. Likewise, the majority of R&D tax-credit coefficients thorough quantiles in both high-tech groups are negative and statistically significant. These results could be framed into the existing empirical evidence of longer unemployment rates couple with lower wage growth rates due a fall in labor market fluidity (Davis and Haltiwanger, 2014).

All in all, results are consistent with a model in which the labor supply of high-tech workers at the state level is sensitive or elastic. The empirical approach applied in this paper unpacks sizeable heterogeneous effects of infrastructure expenditures, incentives (monetary and non-monetary) and innovation outcomes measured as the quantity of technological patents and scientific citations for high-tech industries with different aggregate value shares. Usually, such heterogeneity cannot be captured with conditional mean estimates because of the strong assumptions behind linear models. From an empirical point of view, these generous subsidies involve several and complex relations between firms and workers regardless the contribution of each sector in terms of aggregate value to the economy. Accordingly, in order to have a better understanding of how these public policies work at a firm level, more research is necessary

2.5 Concluding Remarks

This paper examines the effects of regional employment and wages from infrastructure expenditures (public and private), incentives (monetary and non-monetary) and innovation outcomes (i.e. patents and scientific citations) for U.S high-tech industries. One of the novelties of the present paper is the inclusion of non-monetary incentives (proxied by the diffusion of past public policies applied since the 1913's) and the production of ideas (i.e. technological patents and scientific citations) conditional on industry subsectors value share. While in the past other studies focused on event study programs (e.g., the ARRA) or generous tax subsidies towards specific industries (e.g., biotech), this paper brings new perspective on the effectiveness of public policies for regional labor markets. In order to assess the effects of infrastructure, incentives and innovation outcomes, I first identify the sectors for which infrastructure and innovation policies have the largest effects in terms of aggregate value share and different forms of agglomeration economies and thick market externalities (new jobs and better salaries): high-tech industries like computer and electronic product manufacturing, telecommunications and ICT subsectors. Then, I propose a simple regional model in which workers have some kind of mobility and firms make use of both type of incentives: monetary (e.g., tax-credits) and non-monetary (the mere diffusion of past public policies) and infrastructure expenditures (public and private) to highlight the channels.

The first contribution of the paper is the identification of important stylized facts from the U.S business slowdown (e.g., higher knowledge gap and lower market competition between top and bottom innovators in public firms). That is, firms with lower marginal costs are more likely to be benefited from these public policies. The second contribution is an empirical assessment of the channels for which the above-mentioned policies work in regional labor markets. For employment models (under an IV arbitrary framework) and using the number of senators in the appropriation committee as instruments, I find that a 1% increase in the diffusion of past policies leads to a 0.777% increase in employment for the top value added sectors other things equal. In addition, a 1% increase in (public infrastructure) private non-residential spending is associated with a 0.941% increase (decrease of -2.034%) in employment for top value-added (bottom value-added) when conditional innovation outcomes are considered. That is an "enabler" entrepreneurship effect over total and top value-added high-tech employment due to private infrastructure expenditures and a "disabler" negative effect of highway spending only in sectors with lower value share.

Interestingly, the cumulative response of monetary incentives (both generous subsidies as well as firms' user cost) are positively associated to higher job creation rates in bottom rather than top value-added sectors. Contrary to traditional wisdom, R&D tax credits offered by states, imply a positive and (cumulative) response on employment of 20.841% and 54.448% in top and bottom value-added sectors respectively while a 1% reduction in the R&D user cost leads to a 22.703% increase in employment in bottom value added sectors. In the top value added group and industry as a whole, point estimates are statistically significant but less than half compared to those in lower value share sectors (9.225 and 11.553) when conditional patents are considered. Therefore, by assuming a flexible relation among units and time, results show that larger amounts of knowledge in most-innovative sectors do not necessarily imply a higher contribution to employment rates for the aggregate economy. When spatial variables are introduced into the analysis, I find positive but moderate direct effects of public infrastructure. That is coefficients rang from 0.129% to 0.154% indicating that after 8 years highway expenditures increase total high-tech employment. Moreover, including spatial interactions between non-monetary incentives and innovation outcomes in high-tech sectors with a higher aggregate value share leads a 0.183% employment growth i.e. networking (spillover) effects in other states provided that firms stimulate their local economies through increasing rates of ideas (i.e. production of technological patents) due to generous tax-credits.

Finally, a wage decomposition for within high-tech workers is performed. Results confirm the same trends previously observed in the employment analysis. Private infrastructure spending has a positive effect across subsectors and throughout quantiles while the negative impact of public infrastructure is wiped-out after the 20^{th} quantile in top value-added industries. For instance, a 1% increase of highway expenditures in the upper side of the wage distribution leads to a positive and significant impact of 0.041% and a 0.189% in top and bottom value-added sectors respectively. In addition, monetary incentives are positively associated to higher wages in top value-added for workers located at the tails of wage distribution (e.g., 10^{th} quantile) and highly significant. However, as we move across the distribution coefficients become negative and significant, especially for top earners (-4.432%). Conversely, high-tech workers from bottom value-added sectors have on average better salaries in almost all quantiles, especially at the median (4.572%) compared to workers in top value-added sectors. Accordingly, monetary incentives are positively (negatively) associated to higher (lower) salaries in bottom (top) value-added industries which suggests that these generous subsidies do not always lead to higher wages. In the case of both R&D user cost and interactions, results are mixed and should be taken with caution as the presence of labor market regulations like minimum wages may be at work. Therefore, regardless the contribution of each sector in terms of aggregate value to the economy, we retain that more research is necessary because high-tech industries are continuously evolving and the labor supply of high-tech workers is highly elastic.

From a state's perspective, efforts should be concentrated on the empowerment of laggard high-tech sectors and the reduction of the innovation/wage tech gap in terms of aggregate value. Certainly, this would require not only more job-training programs, but also investing these generous R&D subsidies and federal grants into new low-cost technologies tailored on worker's capabilities with soft skills. From an institutional perspective, it is well-known that States spend billions of dollars to attract R&D activity to their jurisdiction(s) to enhance their local economies. The direction of these generous incentives have always been a subject among debate among policymakers because these can generate different forms of agglomeration economies and thick market externalities at both margins (intensive and extensive) for regional labor markets. To the best of my knowledge, this paper shows that infrastructure expenditures coupled with monetary incentives like R&D tax credits and non-monetary incentives like the diffusion of past public policies, may facilitate the transition to achieve such targets in high-tech industries with different aggregate value shares. Unlike earlier studies (Goolsbee, 1998), we sustain a more optimistic perspective of innovation policies in the sense that to have well-remunerated workers, substantial effort by firms (in terms of cost-saving effects) must be done to hire additional workers and provide better salaries. Despite finding networking effects in regards to innovation, the idea that policymakers can stimulate one specific industry (high-tech) and not another one is always questionable given workers' tastes and degree of mobility. For that reason, we hasten to point out whether or not should States support these generous tax-credits or else the minimum conditions in terms of the production of knowledge (patents) relative to the aggregate value share generated by firms to apply for these grants as more research is necessary to understand of how these public policies work at a firm level.

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Figures

FIGURE 2.1: A simple model of regional employment with incentives

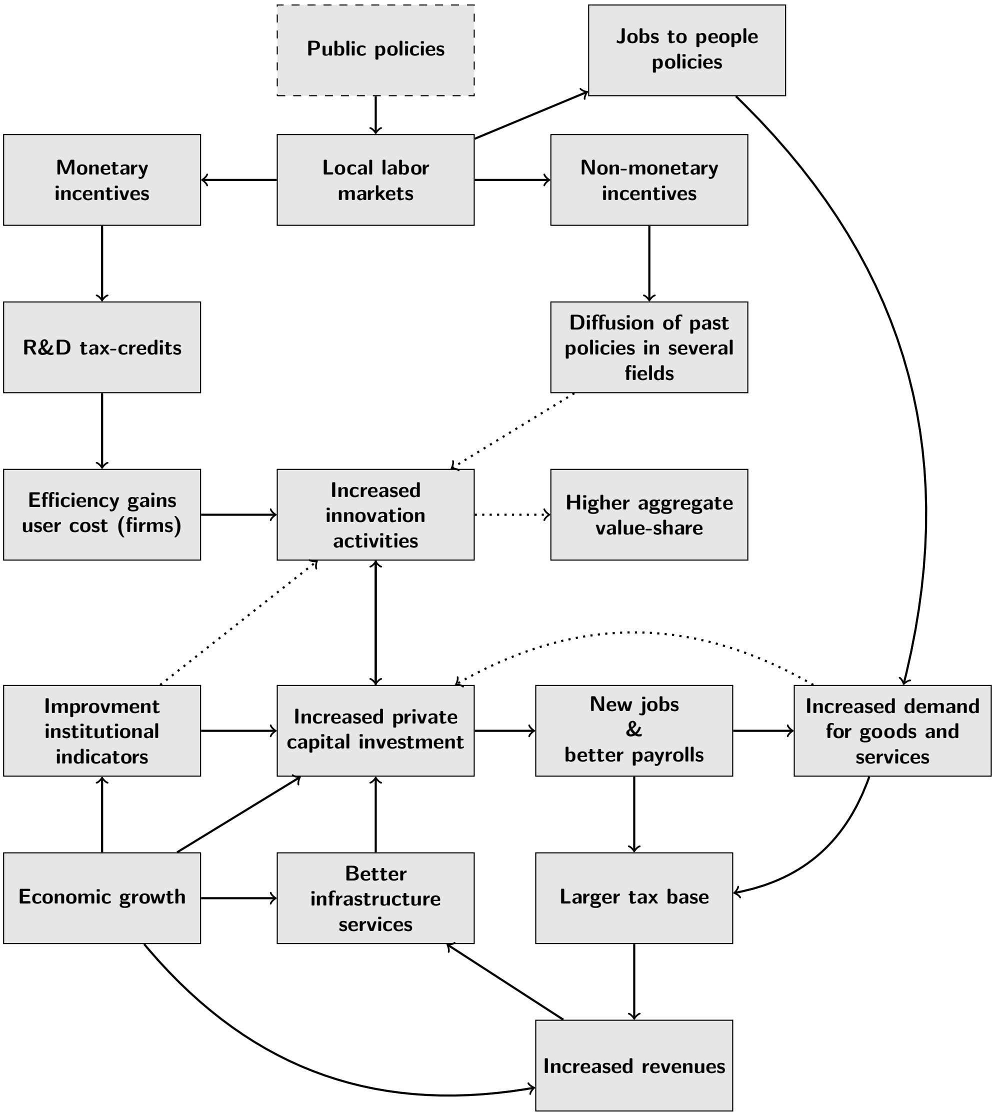
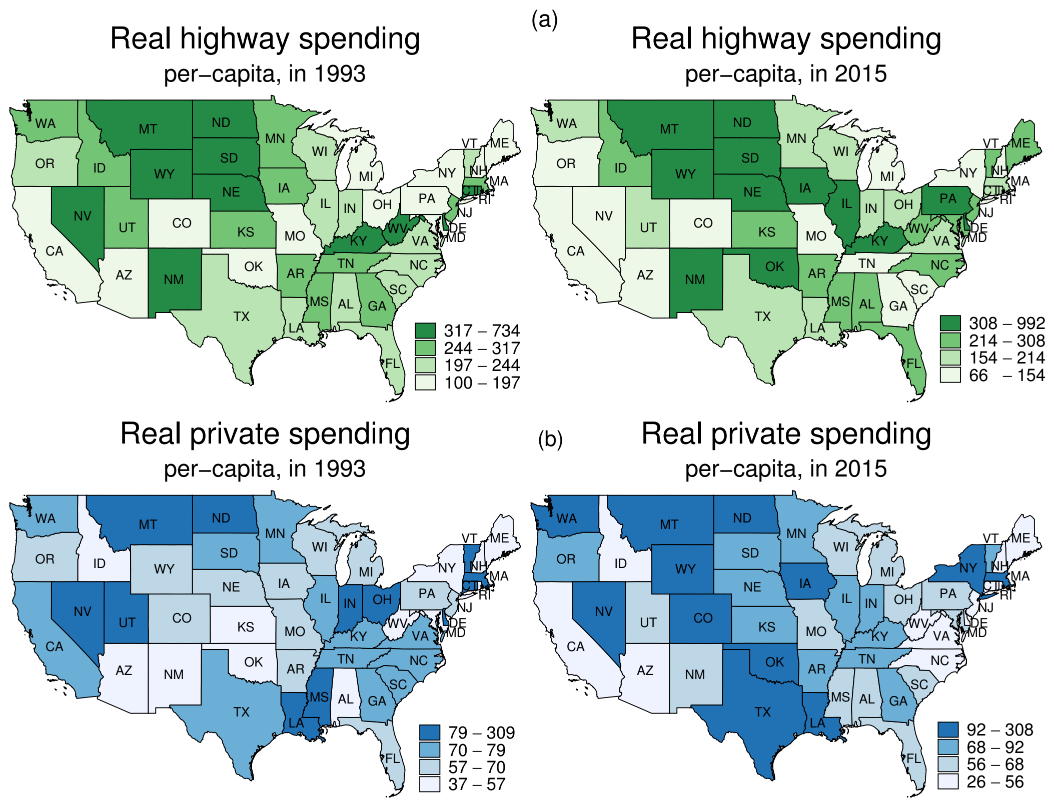
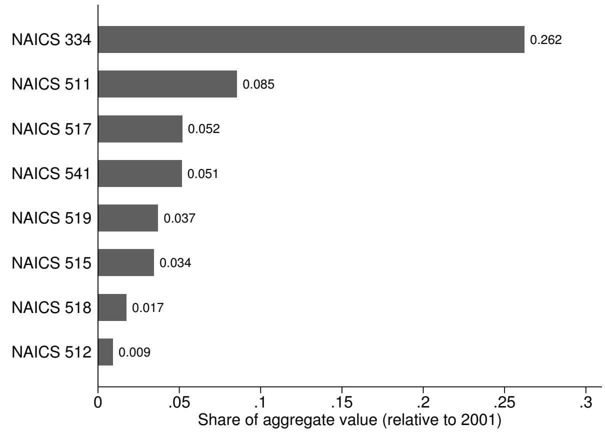


FIGURE 2.2: Public and Private infrastructure



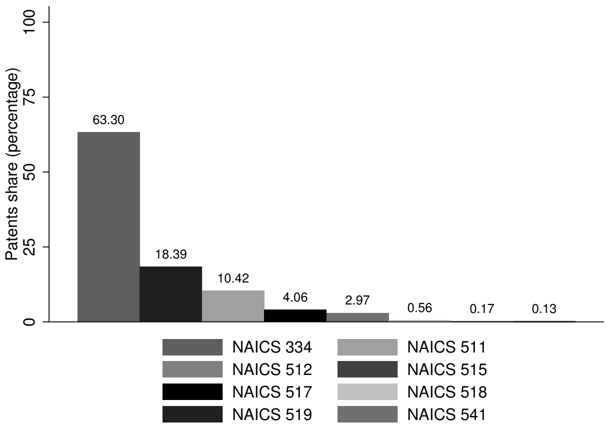
Note: Public infrastructure is defined as highway spending (capital outlays of highway spending which include the following items: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal) while private infrastructure encompass the non-residential spending (available from 1993 onwards). As regards the former, real measures were computed using the State price index provided by the Bureau of Economic Analysis (BEA) which takes into account the price of investment goods (table 3.9.4) whereas the latter variable was deflated using the BLS consumer price index CPI-U (2012=100). In order to control for business cycle effects both variables are defined in per capita terms. The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE 2.3: Average aggregate value share within high-tech industries



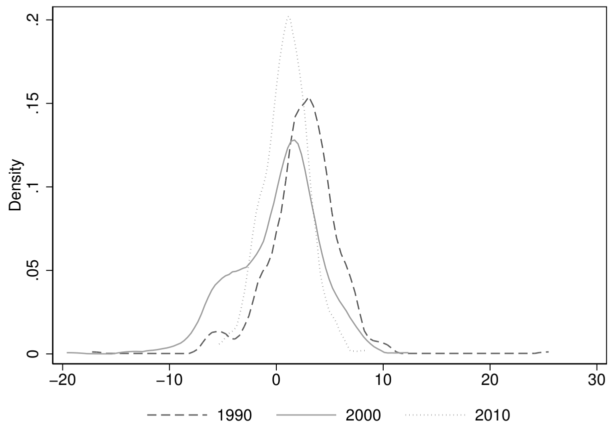
Note: This figure presents the aggregate value share (AV) for U.S public firms in 2001. In doing so, we follow Crouzet and Eberly (2018), Hall (2018) methodology. High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.1 contains a brief description of each sector. Source: author own calculations.

FIGURE 2.4: Share of patents U.S high-tech industries



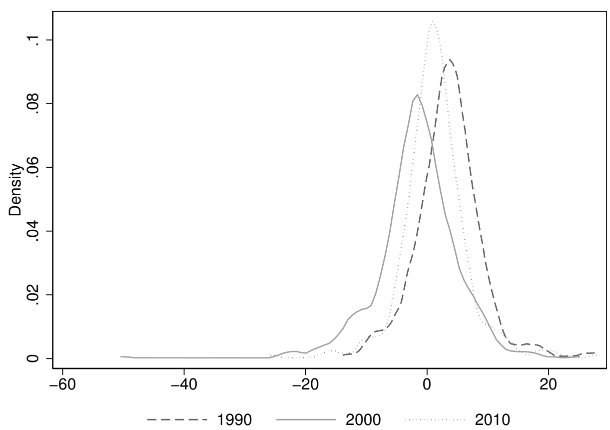
Note: This figure presents the share of patents within high-tech sectors. Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020) and Arora et al. (2017). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.1 contains a brief description of each sector. Source: author own calculations.

Figure 2.5: Densities of high-tech employment: top value-added industries



Note: This figure presents kernel density functions for high-tech employment growth rates by decades. Data is from Quarterly Census of Employment & Wages (QCEW). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 517 and 541 respectively. Appendix A.1 contains a brief description of each sector. The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

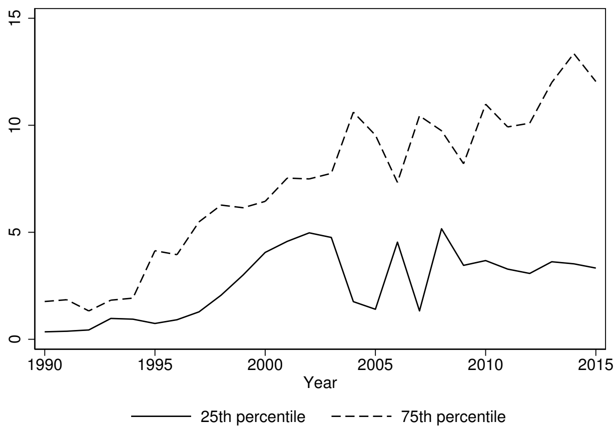
Figure 2.6: Densities of high-tech employment: bottom value-added industries



Note: This figure presents kernel density functions for high-tech employment growth rates by decades. Data is from Quarterly Census of Employment & Wages (QCEW). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 512, 515, 518 and 519 respectively. Appendix A.1 contains a brief description of each sector. The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE 2.7: Distribution of innovation outcomes by quartiles

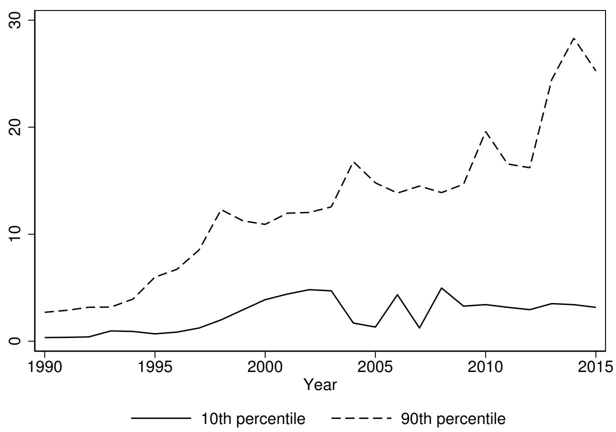
High-tech industries: 1990-2015



Note: Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020) and Arora et al. (2017). The quartiles of per capita patents are constructed as the weighted sum of aggregate value share (AV) of U.S public firms in 2001 (Crouzet and Eberly, 2018, Hall, 2018). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.1 contains a brief description of each sector. For a clear visual inspection, patents are rescaled per 100,000 population and transformed into logarithms. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE 2.8: Distribution of innovation outcomes: top and bottom percentiles

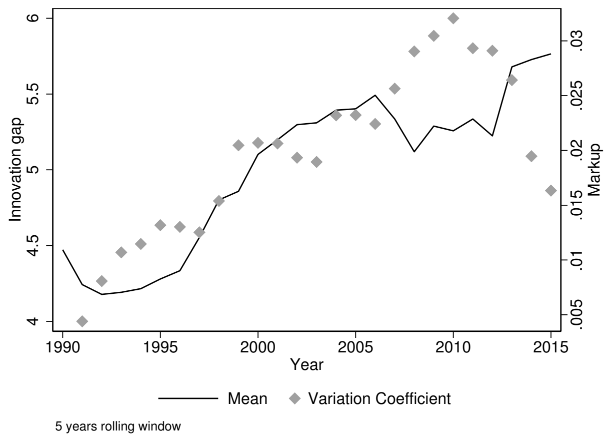
High-tech industries: 1990-2015



Note: Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020) and Arora et al. (2017). The percentiles of per capita patents are constructed as the weighted sum of aggregate value share (AV) of U.S public firms in 2001 (Crouzet and Eberly, 2018, Hall, 2018). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.1 contains a brief description of each sector. For a clear visual inspection, patents are rescaled per 100,000 population and transformed into logarithms. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE 2.9: Innovation gap and market concentration

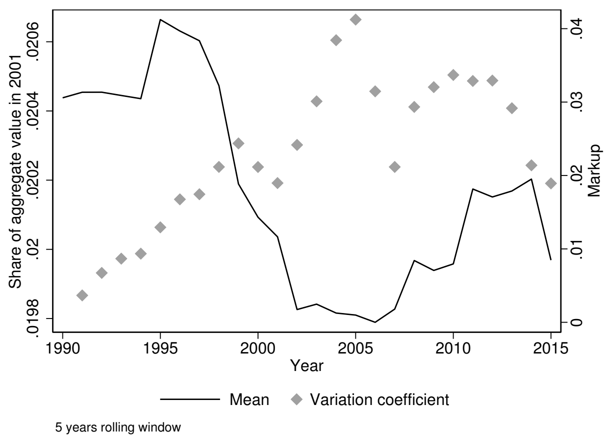
High-tech industries: 1990-2015



Note: Innovation gap (line) is the difference between the top and bottom percentiles of patents and scientific citations (i.e., 90^{th} and 10^{th}) whereas the markup (dots) of public U.S firms (COMPUSTAT) was calculated following Crouzet and Eberly (2018) and Hall (2018) methodology. High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.1 contains a brief description of each industry. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) as well as States not part of the contiguous United States (Alaska and Hawaii). To avoid business cycles effects, rolling windows are included. Source: author own calculations.

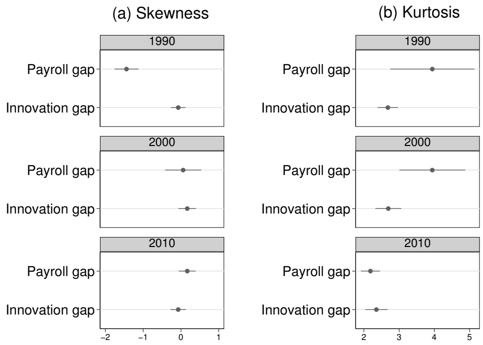
FIGURE 2.10: Share of aggregate value and market concentration

High-tech industries: 1990-2015



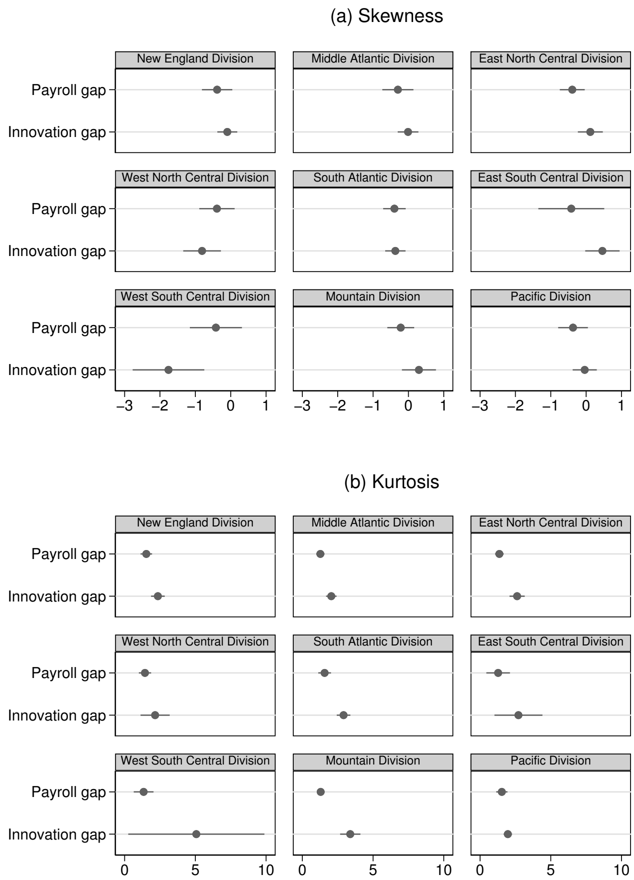
Note: Aggregate value share in 2001 (line) and markup (dots) of public U.S firms (COMPUSTAT) were calculated following Crouzet and Eberly (2018) and Hall (2018) methodology. High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.1 contains a brief description of each industry. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) as well as States not part of the contiguous United States (Alaska and Hawaii). To avoid business cycles effects, rolling windows are included. Source: author own calculations.

FIGURE 2.11: Wage gap and innovation gap: dispersion by decades



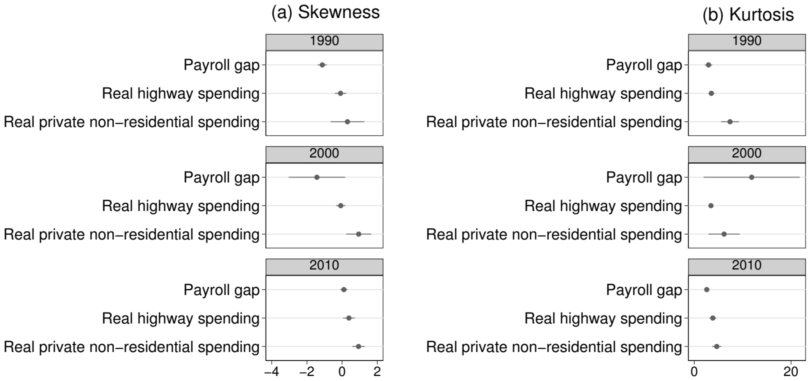
Note: Payroll gap is the difference between the 90^{th} and 10^{th} percentile of real wages; innovation gap is the difference between 90^{th} and 10^{th} patents and scientific citations. Source: Author own calculations based on County Business Paterns (CBP), patents view, a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020) and Arora et al. (2017).

FIGURE 2.12: Wage gap and innovation gap: dispersion by divisions



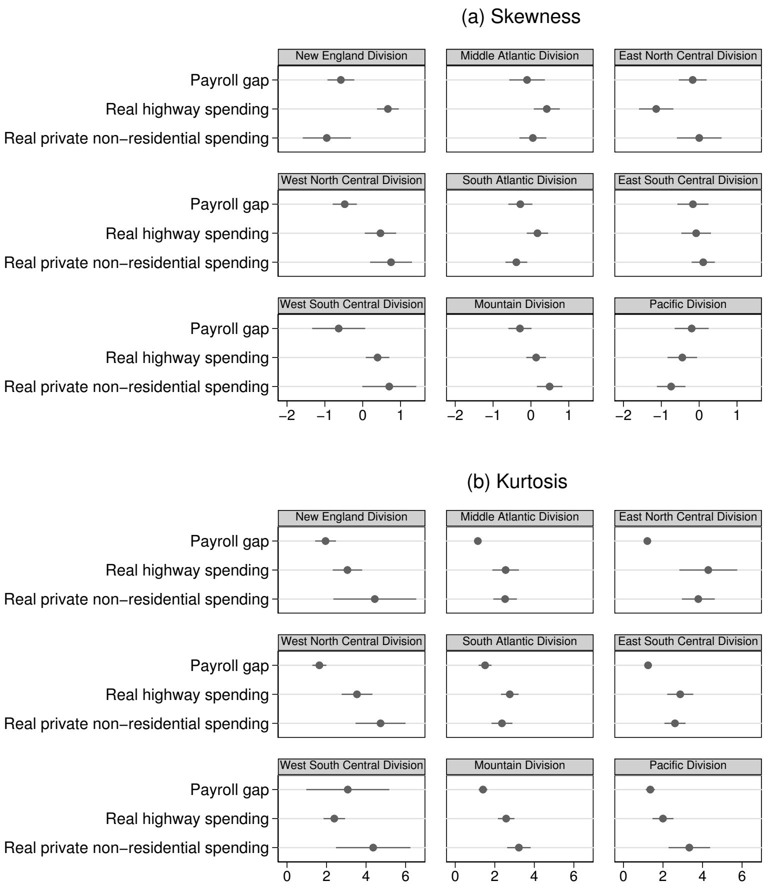
Note: Payroll gap is the difference between the 90^{th} and 10^{th} percentile of real wages; innovation gap is the difference between 90^{th} and 10^{th} patents and scientific citations. Source: Author own calculations based on County Business Paterns (CBP), patents view, a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020) and Arora et al. (2017).

FIGURE 2.13: Wage gap and infrastructure: dispersion by decades



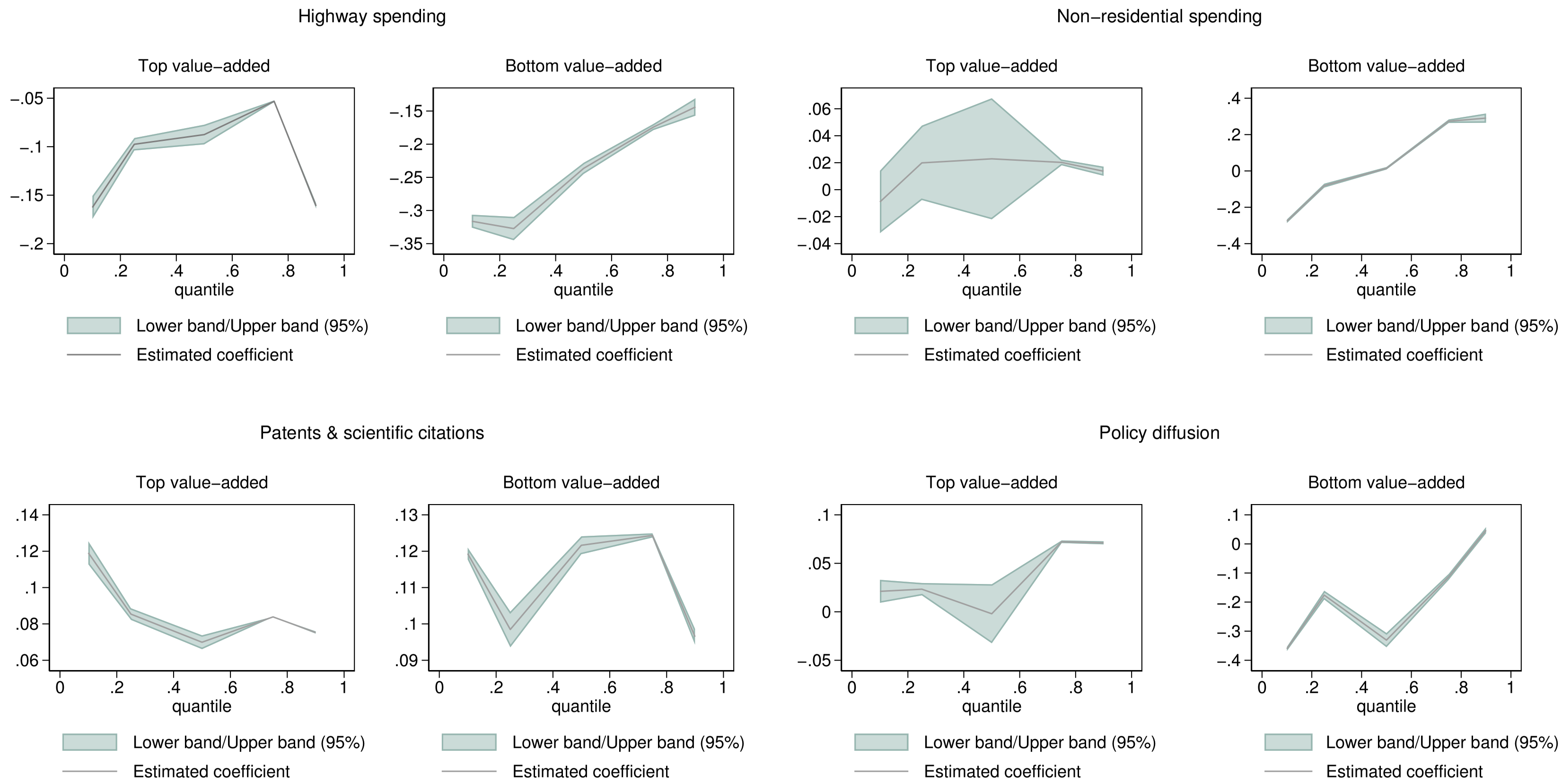
Note: Payroll gap is the difference between the 90^{th} and 10^{th} percentile of real wages; real highway spending includes all capital outlays. Real measures were computed using the State price index (BEA) and the CPI-U (2012=100). Source: Author own calculations based on County Business Paterns (CBP), Pierson et al. (2015) and BLS.

FIGURE 2.14: Wage gap and infrastructure: dispersion by divisions



Note: Payroll gap is the difference between the 90^{th} and 10^{th} percentile of real wages; real highway spending include all capital outlays. Real measures were computed using the State price index (BEA) and the CPI-U (2012=100). Source: Author own calculations based on County Business Paterns (CBP), Pierson et al. (2015) and BLS.

FIGURE 2.15: Wages, infrastructure and innovation outcomes: Quantile panel regression with nonadditive fixed effects



Note: The quantile panel model with nonadditive fixed effects is estimated including the GDP growth rate (excluding both measures of infrastructure) and dummies by U.S Census division and decades. Robust standard errors in brackets are computed by bootstrap method with 800 replications using the Metropolis-within-Gibbs sampler. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Tables

TABLE 2.1: Summary statistics

Variable	Mean	SD	Min	Max
Highway spending	269.100	128.100	65.690	1,081
Private non-residential spending	88.450	47.100	11.850	505.600
(log of) Employment (top value-added)	11.690	1.100	9.259	14.320
(log of) Employment (bottom value-added)	9.491	1.070	7.016	12.640
(log of) Real wage (top value-added)	10.720	0.941	8.195	13.080
(log of) Real wage (bottom value-added)	10.380	0.890	8.125	12.810
(log of) Real GDP per capita	10.740	0.191	10.250	11.390
(growth rate) RGDP per capita (net infrastructure)	1.215	3.454	-16.440	14.570
Population density (100 s persons per sqmi)	1.901	2.555	0.048	12.180
Unemployment rate	5.582	1.888	2.300	13.700
High-school graduation rate	0.627	0.043	0.499	0.748
College graduation rate	0.178	0.042	0.079	0.306
Patents per capita (all high-tech)	6.908	17.190	0.000	173.800
Patents per capita (10^{th} percentile)	2.843	14.290	0.000	173.800
Patents per capita (25^{th} percentile)	2.918	14.280	0.000	173.800
Patents per capita (75^{th} percentile)	8.001	23.030	0.000	276.100
Patents per capita (90^{th} percentile)	14.010	31.610	0.000	333.100
Share of aggregate value (all high-tech)	0.020	0.002	0.012	0.029
Average markup (all high-tech)	1.828	0.210	0.862	2.005
Policy diffusion score	0.047	0.022	0.000	0.175
R&D user cost	1.144	0.022	1.105	1.202
Government spending score	6.684	1.535	2.781	9.701
Tax distortion score	5.660	0.890	2.560	7.760
Labor market friction score	5.485	1.074	1.771	8.670
Economic freedom score	5.944	0.928	2.967	8.046
Observations		1104		

Notes:
a. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and normalized by state population to control for business cycle effects.
b. Real private non-residential spending comes from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and normalized by state population to control for business cycle effects. Data starts from 1993 onwards.
c. Job-creation rates (private employment) are calculated as the difference of the ratio in annual employment levels in period t with respect to t-1 times 100 and nominal wage bills (i.e., annual payrolls) were deflated using the BLS consumer price index CPI-U (2012=100) and rescaled into logarithms. Source: Quarterly Census of Employment & Wages (QCEW).
d. Population density is built dividing the land area (Sq. mi.) of the U.S Census by state population while annual unemployment rate data comes from the BLS civilian civilian noninstitutional population.
e. Education attainment (per-capita) data comes from Frank (2009), unemployment rates are taken from the Bureau Labor Statistics.
f. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.
g. Patents data comes from Arora et al. (2017), patents view and a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020). The percentiles of per capita patents are constructed as the weighted sum of aggregate value share (AV) of U.S public firms in 2001. In lieu with economic literature, patents are rescaled per 100,000 population. Average markups and aggregate 2001 value of public U.S firms were calculated following Crouzet and Eberly (2018) and Hall (2018) methodology.
h. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.2 lists the full set of policies.
i. R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90th percentile) which is about half of the IRS income data (i.e., 0.2588).
j. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were excluded from the analysis. Source: author own calculations.

TABLE 2.2: Correlations: Infrastructure, employment, innovation and wages

	Highway spending		Private non-residential spending		Innovation	
	Panel A					
Census Division	Top value-added	Bottom value-added	Top value-added	Bottom value-added	Top value-added	Bottom value-added
New England	0.061	−0.101	0.024	0.185*	0.199**	0.020
Middle Atlantic	−0.156	−0.111	0.177	0.064	0.111	−0.130
East North	−0.170*	−0.122	0.117	−0.113	0.067	0.124
West North	0.069	−0.122	0.137	−0.133	0.146*	−0.118
South Atlantic	−0.058	−0.256**	0.205**	0.169**	0.026	0.015
East South	−0.118	−0.126	0.123	0.012	−0.138	0.068
West South	−0.175	−0.233**	0.057	−0.059	−0.101	−0.224**
Mountain	−0.094	−0.172**	0.199**	0.105	0.034	−0.085
Pacific	0.100	0.052	0.328**	0.051	0.141	0.445***
All Divisions	−0.029	−0.146***	0.154***	0.076**	0.063*	0.003
	Panel B					
Census Division	Top value-added	Bottom value-added	Top value-added	Bottom value-added	Top value-added	Bottom value-added
New England	−0.386***	−0.444***	−0.481***	−0.523***	0.003	0.057
Middle Atlantic	0.369**	0.218*	−0.203*	−0.127	0.372**	0.307**
East North	0.129	0.148	−0.156	−0.270**	0.354***	0.456***
West North	0.715***	0.653***	0.273**	0.215**	0.388***	0.338***
South Atlantic	0.348***	0.346***	−0.451***	−0.456***	−0.111	−0.086
East South	0.060	−0.050	−0.306**	−0.248**	0.539***	0.487***
West South	0.275**	0.306**	−0.205**	−0.182	−0.166	−0.181
Mountain	0.645***	0.638***	−0.253**	−0.219**	−0.030	−0.040
Pacific	0.649***	0.540***	0.349**	0.222*	0.407**	0.404**
All Divisions	0.395***	0.382***	−0.020	−0.037	0.085**	0.090**
	Panel C					
Census Division	$P25^{th}$	$P75^{th}$	$P25^{th}$	$P75^{th}$	$P25^{th}$	$P75^{th}$
New England	−0.094	0.023	−0.449***	−0.142	0.699***	0.164*
Middle Atlantic	0.053	−0.337**	0.084	0.483***	0.335***	0.182
East North	0.211**	0.529***	0.229**	0.224**	0.478***	0.033
West North	0.563***	0.090	0.239**	0.052	0.654***	0.306**
South Atlantic	0.364***	0.428***	−0.304***	−0.338***	0.790***	0.846***
East South	0.776***	0.290**	−0.261**	−0.223*	0.283**	0.283**
West South	0.278**	0.030	−0.613***	−0.239*	0.954***	0.306**
Mountain	0.321***	0.234**	−0.153**	−0.116	0.609***	0.481***
Pacific	0.592***	0.565***	0.380**	0.138	0.935***	0.751***
All Divisions	0.355***	0.250***	−0.010	−0.004	0.756***	0.605***
	Panel D					
Census Division	$P10^{th}$	$P90^{th}$	$P10^{th}$	$P90^{th}$	$P10^{th}$	$P90^{th}$
New England	0.107	0.223	−0.288**	0.330***	0.289**	−0.738***
Middle Atlantic	−0.183	−0.458***	0.197	0.432***	0.008	0.063
East North	−0.086	0.315**	−0.205**	−0.085	0.045	−0.352***
West North	0.264**	−0.629***	0.205**	−0.235**	0.249**	−0.449***
South Atlantic	0.074	0.145*	−0.337**	−0.331**	0.158**	0.286
East South	0.531***	0.142	−0.121	−0.050	0.198	0.107
West South	0.278**	−0.283**	−0.241*	0.569***	0.491***	−0.934***
Mountain	0.195**	−0.088	−0.160*	−0.002	0.503***	−0.059
Pacific	0.350**	−0.115	−0.109	−0.381**	0.474***	−0.160**
All Divisions	0.197***	−0.163***	−0.046	0.038	0.333**	−0.237**

Notes:

a. The first two panels show the relation among infrastructure, employment, innovation outcomes (Panel A) and wage bills (Panel B) for the top and bottom value-added high-tech sectors, whilst Panels C and D consider only the relationship between infrastructure expenditures and wage bills of all high-tech industries through the lens of a different innovation outcome.

b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4), rescaled by state population to control for business cycle effects.

c. Real private non-residential spending comes from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.

d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Nominal wage bills (i.e., annual payrolls) were deflated by the BLS consumer price index CPI-U (2012=100) rescaled by state population. Source: Quarterly Census of Employment & Wages (QCEW).

e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.

f. For innovation outcomes (third column) we consider two measures. In Panels A and B we regard as a proxy of innovation the diffusion of public policies (score) in the fields of: macroeconomics, labor, education, environment, energy, housing and domestic commerce. Overall, at a State level there are 204 policies that have been diffused among states since the 1913's. Appendix A.2 lists the full set of policies.

g. In Panels C and D we use the 25^{th}, 75^{th}, 10^{th} and 90^{th} percentiles of per capita patents from U.S public firms (COMPUSTAT) weighted by their respective share of aggregate value in 2001 (Crouzet and Eberly, 2018, Hall, 2018). In lieu with economic literature as well as the U.S. Patent and Trademark Office's (USPTO), we normalize patents per 100,000 population.

h. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). For statistical convenience, all variables are rescaled into logarithms. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. Source: author own calculations.

TABLE 2.3: Infrastructure, employment and incentives: GMM Estimates

dv: job creation rate	All			Top value-added			Bottom value-added		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
(log of) Real highway spending	−0.241	−0.270	−1.019**	−0.194	−0.213	−1.001**	−2.285**	−2.279**	−2.025**
	[0.341]	[0.355]	[0.460]	[0.351]	[0.364]	[0.476]	[0.663]	[0.675]	[0.878]
(log of) Real non-residential spending	0.740**	0.724**	0.939**	0.888**	0.881**	1.064**	0.545	0.416	0.762
	[0.275]	[0.276]	[0.395]	[0.278]	[0.280]	[0.421]	[0.588]	[0.585]	[0.734]
(log of) Policy diffusion score	0.799**	0.809**	0.774**	0.893**	0.896**	0.777**	0.366	0.442	0.692
	[0.296]	[0.296]	[0.321]	[0.305]	[0.304]	[0.330]	[0.493]	[0.494]	[0.651]
R&D incentive (0-3 years)			36.013**			27.736*			61.375**
			[15.878]			[16.791]			[21.741]
R&D user cost (0-3 years)			−6.346			−7.155			−15.769**
			[4.674]			[4.918]			[7.575]
High-tech incentive × R&D user cost			−10.570**			−8.166*			17.889**
			[4.647]			[4.912]			[6.334]
GDP growth rate (net infrastructure)	0.175***	0.176***	0.118***	0.175***	0.175***	0.117**	0.152**	0.160**	0.089
	[0.032]	[0.032]	[0.033]	[0.033]	[0.033]	[0.035]	[0.074]	[0.074]	[0.066]
Hansen J test (p-value)	(0.482)	(0.512)	(0.275)	(0.649)	(0.661)	(0.374)	(0.815)	(0.830)	(0.496)
Underidentification test (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Exogeneity test (p-value)	(0.837)	(0.835)	(0.710)	(0.891)	(0.890)	(0.829)	(0.581)	(0.594)	(0.335)
AR Weak IV test (p-value)	(0.556)	(0.577)	(0.107)	(0.732)	(0.738)	(0.167)	(0.061)	(0.070)	(0.173)
CSD_W	0.256	2.976	−2.803	0.755	−1.333	2.243	0.344	2.877	1.504
R-squared (uncentered)	0.218	0.219	0.435	0.216	0.216	0.420	0.067	0.069	0.249
Number of states	48	48	48	48	48	48	48	48	46
Number of observations	1007	1007	1007	992	992	992	893	893	867
Geography controls	N	Y	Y	N	Y	Y	N	Y	Y
Socioeconomic controls	N	N	Y	N	N	Y	N	N	Y
Institutional controls	N	N	Y	N	N	Y	N	N	Y
Supply controls	N	N	Y	N	N	Y	N	N	Y

Notes:

a. All models include Census divisions fixed effects. Additionally, since annual public expenditures vary in sample size, I include a dummy break to account for time fixed effects without compromising the number of covariates. Indeed, its inclusion (not reported) was highly significant in almost all specifications, meaning that this effect cannot be disregarded. Geography controls include average temperatures in winter (January) and summer (July) while socioeconomic ones regard the high school and college graduation rates from total state population. Last but not least, we account for the institutional quality by employing all the disaggregated scores (i.e., subcategories) of the EFNA named: Government spending, Taxation and Labor Market Freedom. For more details see Appendix A.2. Finally, we control for supply shocks with a dummy variable equal to one when the economy had downturns periods (e.g., 1990-91, 2001 and 2008-2010) and zero in contrary case.

b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and rescaled into logarithms.

c. Real private non-residential spending comes from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.

d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Source: Quarterly Census of Employment & Wages (QCEW).

e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value share— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.

f. For the high-tech incentive dummy we consider those states in which R&D tax-credits were positive. Data comes from the Panel Database of Incentives and Taxes (PDIT) Bartik (2017). While R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90^{th} percentile) which is about half of the IRS income data (i.e., 0.2588).

g. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.3 lists the full set of policies.

h. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were excluded from the analysis. Also we account for outliers (Delaware, Maine).

i. The total number of draws of the weighted CSD statistic were set to 10 to avoid distortions from lower order terms. In this way, the statistic can be constructed accounting for both serial correlation and CSD (Juodis and Reese, 2021). Autocorrelated standard errors (HAC) with the Newey-West bandwidth adjustment in brackets small sample adjustment. The number of optimal lags for the bandwidth is set to 3. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: author own calculations.

TABLE 2.4: Infrastructure, employment, incentives and innovation: GMM Estimates

dv: job creation rate	All			Top value-added			Bottom value-added		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
(log of) Real highway spending	−0.780	−0.792	−1.490**	−0.644	−0.647	−1.399**	−2.719**	−2.748**	−2.846**
	[0.497]	[0.497]	[0.541]	[0.513]	[0.514]	[0.556]	[0.898]	[0.895]	[0.998]
(log of) Real non-residential spending	1.037**	0.982**	1.220**	1.138**	1.098**	1.338**	0.316	0.216	0.847
	[0.339]	[0.341]	[0.477]	[0.367]	[0.370]	[0.513]	[0.655]	[0.655]	[0.834]
(log of) Patents (10^{th} percentile)	0.044	0.036	0.113	0.004	−0.000	0.095	0.127	0.109	0.177
	[0.114]	[0.114]	[0.096]	[0.113]	[0.112]	[0.097]	[0.209]	[0.211]	[0.191]
(log of) Patents (25^{th} percentile)	−0.540*	−0.522*	−0.463	−0.385	−0.376	−0.422	−0.836*	−0.812	−0.651
	[0.312]	[0.311]	[0.315]	[0.327]	[0.326]	[0.320]	[0.506]	[0.509]	[0.541]
(log of) Patents (75^{th} percentile)	0.490*	0.483*	0.518**	0.372	0.366	0.419*	0.800*	0.782*	1.191**
	[0.256]	[0.259]	[0.245]	[0.247]	[0.252]	[0.249]	[0.441]	[0.442]	[0.441]
(log of) Patents (90^{th} percentile)	−0.220**	−0.210*	−0.194	−0.169	−0.162	−0.132	−0.328	−0.313	−0.523**
	[0.109]	[0.110]	[0.128]	[0.110]	[0.112]	[0.131]	[0.204]	[0.203]	[0.209]
R&D incentive (0-3 years)			33.998*			25.927			60.460**
			[17.850]			[18.744]			[24.012]
R&D user cost (0-3 years)			−11.248**			−10.935*			−21.681**
			[5.508]			[5.682]			[8.238]
High-tech incentive × R&D user cost			−9.972*			−7.631			−17.582**
			[5.211]			[5.471]			[6.990]
GDP growth rate (net infrastructure)	0.202***	0.203***	0.113**	0.196***	0.196***	0.112**	0.152**	0.158**	0.070
	[0.040]	[0.040]	[0.035]	[0.041]	[0.041]	[0.037]	[0.077]	[0.077]	[0.067]
Hansen J test (p-value)	(0.395)	(0.436)	(0.277)	(0.527)	(0.552)	(0.362)	(0.847)	(0.859)	(0.405)
Underidentification test (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Exogeneity test (p-value)	(0.725)	(0.734)	(0.558)	(0.812)	(0.814)	(0.786)	(0.646)	(0.649)	(0.203)
AR Weak IV test (p-value)	(0.303)	(0.330)	(0.047)	(0.488)	(0.509)	(0.090)	(0.149)	(0.145)	(0.070)
R-squared (uncentered)	0.204	0.206	0.458	0.196	0.196	0.435	0.071	0.073	0.293
Number of states	45	45	45	45	45	45	45	45	44
Number of observations	812	812	812	805	805	805	752	752	739
Geography controls	N	Y	Y	N	Y	Y	N	Y	Y
Socioeconomic controls	N	N	Y	N	N	Y	N	N	Y
Institutional controls	N	N	Y	N	N	Y	N	N	Y
Supply controls	N	N	Y	N	N	Y	N	N	Y

Notes:

a. All models include Census divisions fixed effects. Additionally, since annual public expenditures vary in sample size, I include a dummy break to account for time fixed effects without compromising the number of covariates. Indeed, its inclusion (not reported) was highly significant in almost all specifications, meaning that this effect cannot be disregarded. Geography controls include average temperatures in winter (January) and summer (July) while socioeconomic ones regard the high school and college graduation rates from total state population. Last but not least, we account for the institutional quality by employing all the disaggregated scores (i.e., subcategories) of the EFNA named: Government spending, Taxation and Labor Market Freedom. For more details see Appendix A.2. Finally, we control for supply shocks with a dummy variable equal to one when the economy had downturns periods (e.g., 1990-91, 2001 and 2008-2010) and zero in contrary case.

b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and rescaled into logarithms.

c. Real private non-residential spending comes from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.

d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Source: Quarterly Census of Employment & Wages (QCEW).

e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value share— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.

f. For the high-tech incentive dummy we consider those states in which R&D tax-credits were positive. Data comes from the Panel Database of Incentives and Taxes (PDIT) Bartik (2017). While R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90^{th} percentile) which is about half of the IRS income data (i.e., 0.2588).

g. The analysis excludes States with missing data (West Virginia, Wyoming), outliers (Delaware, Maine), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Autocorrelated standard errors (HAC) with the Newey-West bandwidth adjustment in brackets small sample adjustment. The number of optimal lags for the bandwidth is set to 3. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table 2.5: Infrastructure, employment and incentives: IV Arbitrary Spatial Estimates

dv: job creation rate	All			Top value-added			Bottom value-added		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
(log of) Highway spending	−0.192	−0.226	−0.107	−0.210	−0.234	−0.285	−2.339***	−2.368***	−1.579**
	[0.272]	[0.263]	[0.349]	[0.276]	[0.270]	[0.355]	[0.642]	[0.628]	[0.641]
(log of) Private non-residential spending	0.729**	0.720**	0.369	0.917**	0.921**	0.561	0.581	0.448	0.526
	[0.285]	[0.291]	[0.445]	[0.273]	[0.280]	[0.373]	[0.546]	[0.530]	[0.790]
(log of) Policy diffusion score	0.774**	0.784**	0.727**	0.851**	0.853**	0.793**	0.358	0.431	0.047
	[0.304]	[0.302]	[0.260]	[0.310]	[0.309]	[0.270]	[0.569]	[0.572]	[0.522]
R&D incentive (0-3 years)			43.881**			27.184**			85.034**
			[13.247]			[12.432]			[25.720]
R&D user cost (0-3 years)			−1.926			−4.339			−1.495
			[4.461]			[3.432]			[9.862]
R&D incentive × R&D user cost			−12.891**			−8.034**			−24.726**
			[3.847]			[3.620]			[7.460]
GDP growth rate (net infrastructure)	0.178***	0.179***	0.112***	0.178***	0.178***	0.100***	0.166**	0.174**	0.087
	[0.028]	[0.029]	[0.026]	[0.031]	[0.031]	[0.028]	[0.072]	[0.073]	[0.063]
Kleibergen-Paap F statistic	460.600	390.100	223.000	443.400	372.700	210.600	333.700	308.300	192.600
Weak IV two-step test	[−0.408;	[−0.341;	[−0.557;	[−0.414;	[−0.350;	[−0.746;	[−3.215;	[−3.055;	[−2.650;
[2sls intervals]	0.560]	0.667]	0.572]	0.606]	0.668]	0.413]	−1.033]	−0.854]	−0.080]
CSD_W statistic	4.711	0.251	−1.452	0.473	0.605	−2.485	−2.433	−1.798	−0.928
R-squared (uncentered)	0.219	0.219	0.360	0.216	0.216	0.367	0.067	0.070	0.175
Number of states	48	48	48	48	48	48	48	48	48
Number of observations	1007	1007	1007	992	992	992	893	893	893
Geography controls	N	Y	Y	N	Y	Y	N	Y	Y
Socioeconomic controls	N	N	Y	N	N	Y	N	N	Y
Institutional controls	N	N	Y	N	N	Y	N	N	Y
Supply controls	N	N	Y	N	N	Y	N	N	Y

Notes:
a. All models include Census divisions fixed effects. Additionally, since annual public expenditures vary in sample size, I include a dummy break to account for time fixed effects without compromising the number of covariates. Indeed, its inclusion (not reported) was highly significant in almost all specifications, meaning that this effect cannot be disregarded. Geography controls include average temperatures in winter (January) and summer (July) while socioeconomic ones regard the high school and college graduation rates from total state population. Last but not least, we account for the institutional quality by employing all the disaggregated scores (i.e., subcategories) of the EFNA named: Government spending, Taxation and Labor Market Freedom. For more details see Appendix A.1. Finally, we control for supply shocks with a dummy variable equal to one when the economy had downturns periods (e.g., 1990-91; 2001 and 2008-2010) and zero in contrary case.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and rescaled into logarithms.
c. Real private non-residential spending was obtained from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Source: Quarterly Census of Employment & Wages (QCEW).
e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value share— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.
f. For the high-tech incentive dummy we consider those states in which R&D tax-credits were positive. Data comes from the Panel Database of Incentives and Taxes (PDIT) (Bartik, 2017). While R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90^{th} percentile) which is about half of the IRS income data (i.e., 0.2588).
g. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.2 lists the full set of policies.
h. We employ the LC test for inefficient matrix with a coverage distortion of 5% (i.e. 95% confidence level) and 250 grid points to form a two-step identification-robust confidence set. The total number of draws of the weighted CSD statistic were set to 10 to avoid distortions from lower order terms. In this way, the statistic can be constructed accounting for both serial correlation and CSD (Juodis and Reese, 2021).
i. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were excluded from the analysis. Standard errors HAC corrected for arbitrary cluster correlation in brackets. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

TABLE 2.6: Infrastructure, employment, incentives and innovation: IV Arbitrary Spatial Estimates

dv: job creation rate	All			Top value-added			Bottom value-added		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
(log of) Real highway spending	−0.906**	−0.921**	−0.736*	−0.818**	−0.823**	−0.744*	−2.768**	−2.791**	−2.034**
	[0.363]	[0.368]	[0.430]	[0.371]	[0.374]	[0.428]	[0.825]	[0.833]	[0.876]
(log of) Real non-residential spending	1.024**	0.960**	1.024**	1.156**	1.107**	0.941**	0.548	0.413	1.276
	[0.349]	[0.347]	[0.446]	[0.366]	[0.368]	[0.474]	[0.587]	[0.577]	[0.806]
(log of) Patents (10^{th} percentile)	0.022	0.008	0.037	−0.016	−0.024	0.003	0.221	0.204	0.186
	[0.081]	[0.083]	[0.069]	[0.075]	[0.077]	[0.072]	[0.218]	[0.222]	[0.162]
(log of) Patents (25^{th} percentile)	−0.431**	−0.417**	−0.445**	−0.291	−0.284	−0.303	−1.258*	−1.242*	−1.357**
	[0.190]	[0.192]	[0.188]	[0.193]	[0.195]	[0.212]	[0.660]	[0.660]	[0.666]
(log of) Patents (75^{th} percentile)	0.471**	0.462**	0.485**	0.361**	0.355**	0.322**	0.715	0.674	1.167**
	[0.161]	[0.164]	[0.142]	[0.150]	[0.154]	[0.140]	[0.436]	[0.424]	[0.370]
(log of) Patents (90^{th} percentile)	−0.188**	−0.180**	−0.255**	−0.143*	−0.138*	−0.172*	−0.391**	−0.369**	−0.590**
	[0.076]	[0.076]	[0.099]	[0.076]	[0.076]	[0.098]	[0.188]	[0.185]	[0.188]
R&D incentive (0-3 years)			28.019**			20.841*			54.448**
			[11.195]			[12.485]			[22.617]
R&D user cost (0-3 years)			−11.553**			−9.225**			−22.703**
			[4.277]			[3.998]			[6.641]
R&D incentive × R&D user cost			−8.253**			−6.150*			−15.890**
			[3.261]			[3.635]			[6.532]
GDP growth rate (net infrastructure)	0.208***	0.210***	0.103***	0.202***	0.204***	0.094**	0.200**	0.204**	0.057
	[0.034]	[0.034]	[0.026]	[0.038]	[0.038]	[0.029]	[0.080]	[0.080]	[0.067]
Kleibergen-Paap F statistic	229.800	225.300	161.100	229.000	224.400	152.200	216.500	211.500	157.500
Weak IV two-step test	[−1.498;	[−1.573;	[−1.602;	[−1.315;	[−1.468	[−1.586;	[−4.541;	[−4.450;	[−3.781;
[2sls intervals]	−0.081]	−0.087]	−0.160]	0.170]	; 0.099]	−0.118]	−1.586]	−1.395]	−0.712]
R-squared (uncentered)	0.207	0.208	0.391	0.198	0.199	0.372	0.086	0.088	0.251
Number of states	48	48	48	48	48	48	48	48	48
Number of observations	833	833	833	826	826	826	764	764	764
Geography controls	N	Y	Y	N	Y	Y	N	Y	Y
Socioeconomic controls	N	N	Y	N	N	Y	N	N	Y
Institutional controls	N	N	Y	N	N	Y	N	N	Y
Supply controls	N	N	Y	N	N	Y	N	N	Y

Notes:
a. All models include Census divisions fixed effects. Additionally, since annual public expenditures vary in sample size, I include a dummy break to account for time fixed effects without compromising the number of covariates. Indeed, its inclusion (not reported) was highly significant in almost all specifications, meaning that this effect cannot be disregarded. Geography controls include average temperatures in winter (January) and summer (July) while socioeconomic ones regard the high school and college graduation rates from total state population. Last but not least, we account for the institutional quality by employing all the disaggregated scores (i.e., subcategories) of the EFNA named: Government spending, Taxation and Labor Market Freedom. For more details see Appendix A.1. Finally, we control for supply shocks with a dummy variable equal to one when the economy had downturns periods (e.g., 1990-91; 2001 and 2008-2010) and zero in contrary case.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and rescaled into logarithms.
c. Real private non-residential spending was obtained from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Source: Quarterly Census of Employment & Wages (QCEW).
e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value share— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.
f. For the high-tech incentive dummy we consider those states in which R&D tax-credits were positive. Data comes from the Panel Database of Incentives and Taxes (PDIT) (Bartik, 2017). While R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90^{th} percentile) which is about half of the IRS income data (i.e., 0.2588).
g. We employ the LC test for inefficient matrix with a coverage distortion of 5% (i.e. 95% confidence level) and 250 grid points to form a two-step identification-robust confidence set.
h. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were excluded from the analysis. Standard errors HAC corrected for arbitrary cluster correlation in brackets. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table 2.7: Spatial autocorrelation test

Variables\Period	1990-94	1995-99	2000-04	2005-09	2010-15
	Moran I statistic				
Employment growth (all high-tech)	0.416***	0.049	0.011	0.046	0.019
(log of) Highway spending	0.065	0.061	0.083*	0.125**	0.141**
(log of) Local aid highway	0.135**	0.205**	0.169**	0.113**	0.063
(log of) Real non-residential spending	0.025	0.056*	−0.007	0.038	0.057
(log of) Policy diffusion score	0.154**	0.093*	0.065	−0.004	0.071
R&D user cost	0.068	0.073	0.081*	0.099**	0.085*

Indicate *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: author own calculations.

Table 2.8: Infrastructure, employment, incentives and innovation: SLX Estimates

Direct effects	(I)	(II)	(III)	(IV)
(log of) Highway spending	0.154*	0.129	0.151*	0.140*
	[0.085]	[0.082]	[0.084]	[0.082]
(log of) Real non-residential spending	0.049	0.051	0.048	0.051
	[0.047]	[0.047]	[0.046]	[0.046]
Patents top value-added (dummy)	0.616**			
	[0.268]			
Patents top bottom-added (dummy)		0.510*		
		[0.295]		
GDP growth rate (net infrastructure)	0.016***	0.016***	0.017***	0.017***
	[0.005]	[0.005]	[0.005]	[0.005]
Indirect effects & Interactions				
W (log of) Highway spending × (log of) Local aid highway	−0.001	−0.002	−0.002	−0.002
	[0.002]	[0.002]	[0.002]	[0.002]
W Incentives (non-monetary) × Patents (top value-added)	0.183**			
	[0.083]			
W Incentives (non-monetary) × Patents (bottom value-added)		0.152		
		[0.096]		
W R&D (monetary incentive)			0.424**	0.431**
			[0.171]	[0.167]
W R&D user cost × Patents (top value-added)			0.026	
			[0.062]	
W R&D user cost × Patents (bottom value-added)				0.033
				[0.043]
Hansen test (p-value)	0.623	0.603	0.661	0.656
Exogeneity test of instruments (p-value)	0.838	0.804	0.836	0.809
Underidentification test (p-value)	(0.000)	(0.000)	(0.000)	(0.000)
Weak IV AR test (p-value)	(0.352)	(0.423)	(0.381)	(0.411)
CSD statistic	−1.470	−1.710	−1.540	−1.520
R-squared (uncentered)	0.489	0.490	0.490	0.491
Number of states	48	48	48	48
Number of observations	864	864	864	864

Notes:
a. I restrict the analysis to all high-tech sectors with non-missing employment data. I applied the BN first difference (standarized) filtering method (Bai and Ng (2002), Bai (2004) and Bai and Ng, 2004) to control for all time effects. The BN (IC2) criteria yields 3 factors. All models include Census divisions fixed effects, geography and aggregate institutional scores as additional controls. Spillover effects are depicted with the W prefix.
b. All spatial lag variables are of order (1), using a power matrix weight (2) and an arbitrary threshold in kilometres. Highway expenditures are instrumented with the same exogenous variables as in non-spatial models. To account for cumulative effects we augment and restrict its number of past predictors only from 4 to 8 lags. Local aid highway are intergovernmental revenues used for roads, streets, and highways.
c. Real private non-residential spending was obtained from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects.
d. Patents is a dummy variable equal to 1 for innovations in the respective (conditional) value-share subsectors and 0 for other aggregated industries: Retail & Construction, Healthcare, Manufacturing and Others (agriculture, finance and mostly services).
e. Non-monetary incentives include the diffusion of 204 policies in education, energy, environment, domestic commerce, housing, labor and macroeconomics at a State level.
f. R&D incentive dummy for high-tech industries is equal to 1 for those states in which tax-credits were positive (Bartik, 2017). R&D user cost was constructed following Wilson (2009) and COMPUSTAT 90^{th} percentile expenditure share (s) (1965-2015) which is about half of the IRS income data (i.e. 0.2588) which is on average 0.1243. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table 2.9: Normality tests for panel data models

	Error (innovation term)			State (specific term)		
Panel A: Top value-added	Skewness	Kurtosis	Joint (p-value)	Skewness	Kurtosis	Joint (p-value)
Coefficient	−0.939***	2.337***	140.530***	−2.291***	6.727**	25.440***
Std.Error	[0.114]	[0.274]	(0.000)	[0.528]	[2.622]	(0.000)
Panel B: Bottom value-added	Skewness	Kurtosis	Joint (p-value)	Skewness	Kurtosis	Joint (p-value)
Coefficient	−0.405**	0.328*	15.370**	−1.777***	2.649*	24.150***
Std.Error	[0.117]	[0.177]	(0.001)	[0.384]	[1.598]	(0.000)

Notes:
a. We perform the analysis for our two industries using the same controls from employment models and dummies by the four U.S aggregated regions (Northeast, Midwest, South and West) and decades.
b. Bootstrap standard errors (500 replications) in brackets while p-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table 2.10: Quantile wage decomposition

Panel A: Top value-added	IV fixed effects	Nonadditive fixed effects				
dv: (log of) Real payroll	(Mean)	q(10)	q(20)	q(50)	q(75)	q(95)
(log of) Highway spending	0.025	−0.113***	−0.052***	0.004***	0.002	0.041***
	[0.073]	[0.003]	[0.004]	[0.001]	[0.002]	[0.011]
(log of) Private non-residential spending	0.028	0.031***	0.088***	0.088***	0.127***	0.097***
	[0.057]	[0.005]	[0.001]	[0.002]	[0.007]	[0.028]
(log of) Patents per-capita	0.017	0.053***	0.035***	0.026***	0.010***	−0.011
	[0.013]	[0.001]	[0.000]	[0.000]	[0.001]	[0.007]
(log of) Policy diffusion score	−0.063	0.029***	0.005**	−0.013***	−0.035***	−0.144***
	[0.044]	[0.005]	[0.002]	[0.001]	[0.002]	[0.011]
R&D incentive (0-3 years)	−2.103	2.005***	0.170***	−0.494***	−2.143***	−4.432***
	[1.375]	[0.004]	[0.004]	[0.001]	[0.004]	[0.057]
R&D user cost (0-3 years)	−2.409***	0.609***	−0.218***	−0.661***	−0.023	0.148
	[0.530]	[0.041]	[0.012]	[0.004]	[0.066]	[0.091]
R&D incentive × R&D user cost	0.579	−0.593***	−0.067***	0.124***	0.601***	1.210***
	[0.398]	[0.000]	[0.001]	[0.000]	[0.002]	[0.011]
Observations	810	847	847	847	847	847
Number of states	46	46	46	46	46	46
Panel B: Bottom value-added	**IV fixed effects**	**Nonadditive fixed effects**				
dv: (log of) Real payroll	(Mean)	q(10)	q(20)	q(50)	q(75)	q(95)
(log of) Highway spending	−0.120	−0.115***	0.017***	−0.150***	−0.232***	0.189*
	[0.085]	[0.004]	[0.006]	[0.009]	[0.026]	[0.109]
(log of) Private non-residential spending	0.001	−0.255***	0.004	−0.015**	−0.094***	0.197
	[0.118]	[0.011]	[0.006]	[0.007]	[0.016]	[0.171]
(log of) Patents per-capita	0.018	0.041***	0.027***	0.055***	0.051***	0.069***
	[0.029]	[0.001]	[0.001]	[0.003]	[0.005]	[0.013]
(log of) Policy diffusion score	−0.150**	−0.241***	−0.304***	−0.188***	−0.037**	−0.348***
	[0.072]	[0.004]	[0.006]	[0.006]	[0.019]	[0.079]
R&D incentive (0-3 years)	5.088	3.056***	−4.982***	4.572***	4.152***	3.400***
	[4.370]	[0.003]	[0.007]	[0.004]	[0.102]	[1.294]
R&D user cost (0-3 years)	3.490***	2.204***	1.441***	4.665***	6.863***	14.779***
	[1.052]	[0.059]	[0.054]	[0.091]	[0.188]	[2.416]
R&D incentive × R&D user cost	−1.508	−0.878***	1.353***	−1.394***	−0.977***	−2.332***
	[1.274]	[0.002]	[0.003]	[0.002]	[0.020]	[0.310]
Observations	751	788	788	788	788	788
Number of states	46	46	46	46	46	46

Notes:
a. Conditional mean estimates correspond to the two-way (Census divisions and decades) fixed effects model. The Hansen test (not reported) which tests the validity of the instruments is not rejected in any of the two groups.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and normalized by state population to control for business cycle effects.
c. Real private non-residential spending was obtained from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and normalized by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Patents are the weighted sum of aggregate value share (AV) of U.S public firms in 2001. In lieu with economic literature, patents are rescaled per 100,000 population. Data comes from Arora et al. (2017), patents view and a crosswalk of U.S public firms (COMPUSTAT) Dorn et al. (2020).
e. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.2 lists the full set of policies.
f. R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90th percentile) which is about half of the IRS income data (i.e., 0.2588).
g. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were automatically excluded from the analysis. Robust standard errors in brackets are computed by bootstrap method with 500 replications using the Metropolis-within-Gibbs sampler. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Chapter 3

Public Infrastructure, electronic Government Procurement (e-GP) Systems and Macroeconomic Performance

3.1 Introduction

Government procurement accounts for a large proportion of total government expenditure and can be as much as 15-25 percent of total global gross domestic product (GDP) (WTO, 2015; OECD, 2019). In some developing countries the proportion of expenditure is as high as 30-35%. The use of e-procurement (also termed e-government procurement, e-GP) has grown in recent years. This form of procurement uses digital technology in procuring and inviting tender for public works, identify potential suppliers of goods and services, to interact with suppliers, to purchase supplies and services in e-marketplaces, as well as for the transfer of payments (Min and Galle (2003); Standing et al., 2007). Experience in some developing countries has shown that e-governance can improve transparency which leads to, among other things, corruption control and poverty reduction (Bhuiyan, 2011). Studies attribute the growing use to the opportunities that e-GP offers for increased efficiency through better quality decision making and planning as well as greater transparency, accountability and cost savings which explains the growing use across the world (see Cho and Choi (2004); Khan (2009); Kim et al. (2009); Lenk (2006); Pathak et al. (2008); Pathak et al. (2009); Bhuiyan (2011); Kerr and Khorana, 2021).

Bangladesh's annual budget on public procurement in 2019 was about US$ 53 billion where US$ 24.1 billion were actually allocated. The share of public procurement of GDP was about 8% and it represented more than 45% of country's national budget in 2018-2019 and the trajectory shows an upward trend for the upcoming years (*World Bank*, 2020). In the early 2000s, governance and institutional constraints like excessive bureaucratic procedures were identified as serious impediments of low quality service and growth (*World Bank*, 2002). These estimated economic losses in public procurement produced wastage costs of more than 1.5% of GDP per annum (ADB, 2011, *World Bank*, 2013).

Accordingly, the country introduced a series of reforms in 2003, 2006 and 2008 to start practicing procurement under a single and legal framework better known as the UNCITRAL model to regulate the eligibility of tenderers, planning, preparation of tenders and evaluations, tender submission and approval procedures, an independent complaint review mechanism, professional misconduct and sanctions, including anti-corruption measures (*World Bank*, 2020). In 2011, this holistic approach was complemented by a digital technology (e-GP) to communicate and support public procurement transactions.

The e-GP is an independent platform and has its own source of revenue from fees of registration, renewal and required documentation for tenders which makes the system self-sustainable. During the last years, its popularity grew considerably as it reduced delays, rampant bid-rigging and collusion amongst bidders. In 2019, 62% of public procurement expenditure (i.e. US$ 15 billion) was processed with e-GP tools, the remaining US$ 9 billion (from the US$ 24.1 billion allocated budget) was not employed using e-GP. Moreover, 1,325 out of 1,362 public organizations across the country and 65,559 bidders have been registered in the e-GP system and 104,988 procurement packages were processed through e-GP systems. Today more than half of the national budget spent on procurement is processed through the e-GP.

In the case of infrastructure, the country spent 1.05% of GDP (ADB, 2017) in 2011 and 1.12% of GDP on average in roads and highways during 2007-2018 (Global Infrastructure Hub). Interestingly, in the aftermath of the reform e-GP systems improved the quality of public services with annual savings of about US$ 150 million i.e. enough money to build 1,500 kilometres of additional rural roads or 3,000 primary schools more in the country. Furthermore, e-GP reduced user cost ratio by more than 12% compared to traditional procurement (Abdallah, 2015). In this manner, e-GP also increased transparency and competition amongst bidders also while political influence diminished bringing more efficiency.

Along the efficiency arguments, studies examining infrastructure investments in roads and highways (e.g., Rioja (2003*b*); Gibson and Rioja, 2017) employ the Logistic Performance Index (LPI) to assess the quality in seven Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela) with respect to top worldwide performers. This paper also uses the LPI for two reasons. First, it tracks the quality of roads, ports, railroads and delivers information technology. Second, it provides a straightforward comparison in terms of infrastructure effectiveness. Unfortunately, the LPI does not contain disaggregated information like the number of registered bidders with e-GP systems, amount of projects processed through e-GP tools and/or e-GP saving costs. Notwithstanding those limitations, the LPI can be useful as a benchmark scenario for conventional procurement to examine the macroeconomic effects of aggregate capital, consumption and price factors when governments employ e-GP tools.

The aim of the present paper is twofold. First, come-up with a quantitative measure of transparency in the use of e-GP services with respect to conventional procurement measures (i.e. LPI). Second, assess whether the use of e-GP systems for infrastructure investments in roads and highways leads to higher aggregate capital stocks (public and private) and/or consumption levels as a result of a higher transparency process in auctions. Finally, the model attempts to match as close as possible Bangladesh income distribution and whether or not the use e-GP can explain the increasing inequality experienced by Bangladeshi workers during the last decade.

This paper contributes to the use of e-GP systems in infrastructure. Using the case of Bangladesh, we assess whether e-GP reduces informational asymmetry for new bidders when the government invests on roads and highways in Bangladesh. The paper uses Bangladesh dataset on e-GP to construct a transparency indicator measure in public procurement. The indicator depends on the percentage of transactions through the use of e-GP systems, i.e. when employed, new information on bidders arrives and governments reduce informational asymmetries and increase the future savings of new infrastructure investments. To put the discussion into content, we build a general equilibrium model with heterogeneous households, incomplete markets and new investments in roads and highways using e-GP systems. We rely on the incomplete markets set up because economies are dynamic i.e. households are heterogeneous as they have different productivity levels and accumulate assets at the beginning of each period to insure against future uncertainty (e.g., the event of unemployment). Moreover, it provides a macroeconomic perspective for policymakers when markets are complete i.e. when all households are identical and have access to the insurance markets when a negative shock arrives.

The paper makes important contributions to the government policymaking literature. First, a higher intensity of e-GP is a necessary but not a sufficient condition to reduce informational asymmetries or the prices paid by governments as it could lead to the so-called "winner's curse" whereby the lowest price bidder is compelled to renegotiate the contract after the award (Soudry, 2004). Instead, a better enforcement of corruption[1] may enhance the capacity of the e-GP systems. For instance, when contractors are physically intimidated by intentionally parties, governments often embark into different measures to improve infrastructure provision

[1] According to the *Transparency International Global Report* (2008) and Daily Star news, during 2008 bureaucrats were responsible for more than 84% of the corruption acts in the Bangladesh's water and sewage sector followed by powerful private individuals and contractors with political links with a 15% on average.

like grassroots organisations (Olken, 2007) to monitor and inform blowing actions and to prevent dishonesty by public officials (Finan et al., 2017). In this manner, a better functioning of e-GP systems will reduce delays in the completion of new infrastructure projects (Lewis-Faupel et al., 2016) by minimizing the informational asymmetries, fraud and other prohibited practises in public procurement projects which are usually regarded as "...one of the most corruption-ridden sectors" (Freedom House, 2010). Hence, policymakers' efforts should focus on internal policies to improve institutional conditions.

Second, consistent with the well-established result of precautionary saving motive for households in the presence of uninsurable shocks, the capital stock under incomplete markets increases (see Carroll (1994); Huggett (1993); Huggett and Ospina, 2001). In other words, Bangladeshi workers with higher labor productivity draws and asset levels work more hours, generate more output and have higher labor marginal products than their less productive and poorer counterparts in complete markets, but they sacrifice consumption. These results are consistent with economies at early stages of development with inelastic labor supply. In addition, results confirm that future uncertainty and lower transparency in government actions enlarges precautionary saving and/or a higher buffer stock of assets a fact that is associated to lower consumption levels in the long run.

The remainder of this chapter is organized as follows. In Section 3.2 provides the context for discussion and the relevant literature. Section 3.3, presents the model. Section 3.4 describes describes the data sources, parametrization, and model solution. Section 3.5 presents the main findings. Section 3.6 concludes with implications for policymaking.

3.2 Related Literature

In 2011, the government of Bangladeshi launched its e-procurement system. This was supported by the World Bank and e-GP was piloted in four procuring entities. Following the success of the pilot, in February 2021 the World Bank approved US$40 million under DIMAPP to increase the coverage of e-GP to cover 1300 public organizations which meant that all procurement activities were online. The e-GP system includes the facility for international bidding, direct contracting, framework agreement, electronic contract management and payment, procurement data analytics, geo-tagging, among others. While big firms have the capability there are specific provisions to support small and medium-sized and women-led enterprises. The new system aims to increase citizen engagement and allows citizen groups in 8 upazilas to monitor contract implementation.

Employing e-GP system for procurement activities brings benefits for the implementing agencies. Governments benefit from efficient procurement management that results in higher competition, transparency, accountability and better quality auditing. From development perspective, an efficient and effective public administration is an essential precondition for economic and social development (Schuppan (2009); Bhuiyan, 2011). Suppliers benefit from the automation of transactions as e-GP reduces processing time and lower bureaucratic burden and transaction costs. This also supports suppliers to also build their reputation that supports the value for money as it enables governments to work with 'good' ones to decrease the number of failed publicly-funded projects (Vinogradov et al. (2014); Klabi et al., 2018). Finally, taxpayers benefit as the tools ensure value for public money. Additionally, e-GP in public procurement reduces information asymmetry with two interlinked effects: first, e-GP systems stimulate competition and facilitate supplier participation in an open market; second, allows procuring agencies to procure quality goods and services at lower prices. Thus, the attributes (open competition, lower prices) are the underlying basis for governments to increasingly employ e-GP systems also improve buyer-vendor relationships (Brandon-Jones and Carey, 2011).

Studies find evidence that implementing e-GP tools promotes transparency, increases accountability, and limits corruption (see Henriksen and Mahnke (2005); Hardy and Williams (2008); Varney (2011); Bhuiyan (2011); Khorana et al. (2015); Becker, 2018). E-GP systems reduce transaction costs, facilitate faster ordering and a wider range of vendor choices, offer streamlined procurement processes characterised by better control over procurement spending, with wider access to alternative buyers and reduced paperwork (Moon (2005); Bendoly and Schoenherr, 2005). E-auctions are commonly used as an e-GP tool to manage procurements. Evidence suggests that e-auctions generate competition, and force suppliers to adjust bids in line with the actual market price, i.e. results in lower costs from competitive bidding, and lower transaction costs from saving time by automating the procurement process (Essig and Arnold (2001); Rai et al., 2006). Contracting authorities are able to aggregate demand across different departments, and at the same time reduce inventory costs and overheads (Croom (2000); Wyld (2002); Kameshwaran et al. (2007); Khorana et al., 2015). Further, transparency and accountability are the underlying basis for developing policies that ensure an effective roll out of e-GP systems to reduce administrative costs and speed up individual procurement procedures (Khorana et al., 2015). In this manner, e-GP systems enhance the overall efficiency of the system by providing higher transparency and accountability, thereby resulting in efficient management and monitoring (Becker, 2018). The overall efficiency of the e-procurement system depends on the ease of access to information on opportunities, and how processes and procedures (procurement plan, award, etc.) are streamlined for wider inclusion of firms in contracting activity. E-GP portals also enable entities to analyse and assess reliable data. It is worth mentioning that e-GP platforms must support cross-operability for economies of scale.

3.3 The Model

3.3.1 Environment

To investigate the impact of e-GP systems on new infrastructure investments, we use a modified version of first generation incomplete[2] markets general equilibrium models with heterogeneous agents (Bewley, 1986, Huggett, 1993) à la Aiyagari (1994), uninsurable (or partly insurable idiosyncratic) but no aggregate shocks (e.g., disruptions caused by Covid-19) and including an endogenous labor supply decision Rioja (2003*a*,*b*) and Gibson and Rioja (2017).

The additional detail in this article with respect to the aforementioned papers is that governments employ e-Procurement (e-GP) tools (e.g., auctions) to manage budget for new infrastructure investments on roads and highways. This provides the suppliers access to information and increases the transparency of auctions which facilitates participation by higher-quality contractors who are more likely to win contracts. At the same time the use of e-GP minimises delays in completion of infrastructure projects (Lewis-Faupel et al., 2016). In theory public investments that use e-GP address institutional bottlenecks and informational asymmetries and hence, are more productive without any increase in maintenance spending.[3] Therefore, the efficiency of investment increases as the depreciation rate of capital falls which implies that public capital utility is extended over time. To this end, we calibrate the model using labor productivity shocks i.e. employment transitions from both formal and informal workers in Bangladesh with different and persistent productivity levels (from low to high) because incomplete markets models à la Aiyagari cannot amplify wealth accumulation. We focus on 2018 because there is no data on e-GP expenditures before that year.[4] The following subsections provide a detailed description of the model.

[2]By incomplete markets I mean that there are no state contingent markets for the household specific shock e.g., unemployment.

[3]In developing countries these expenditures can be ineffective due to weakness in public investment management and poor institutional quality (Keefer and Knack, 2007), the presence of rampant corruption, nepotism and rent-seeking activities (Olken and Pande, 2012). In addition, it may lead to the so-called pork-barrel (Curto-Grau et al., 2012) and/or "white elephants" i.e., large abandoned projects which inevitably become illiquid and have little or no market value at all.

[4]This assumption is suitable when the focus is to match as close as possible the level of wealth at a specific point in time (Castaneda et al., 2003). Certainly, economies are dynamic i.e., agents buy assets (accumulate wealth) at the start of each period to insure against fluctuations in productivity; thereby giving rise to an endogenous wealth distribution. Of course, for calibration the latter requires reliable and longitudinal data on income and employment like surveys which unfortunately; are not always available for developing countries.

3.3.2 Household's problem

The economy is populated by a large number of agents (infinitely-lived households), for convenience its measure is normalized to the unity. As it is common in the heterogeneous-agent incomplete market model environments, agents are atomistic and ex-ante homogeneous but ex-post heterogeneous depending on their idiosyncratic labor productivity shock realizations. In other words, endowments are realized in each period with some agents getting good (i.e lucky) realizations whereas others (unlucky) get a lower ones ("the American dream and American Nightmare" condition). Therefore, households ex-post heterogeneity nature is linked to individual-specific productivity realization shocks z_{t+1} from the same distribution, and since financial markets are incomplete (there is only a risk-free asset available), household's with the ability to insure against future uncertainty will buy assets. For instance, in the event of becoming less productive in the future, household's with higher productivity levels will accumulate wealth through assets while those with lower productivity levels will not have that possibility.

In this framework, households have identical preferences, i.e. derive utility from consumption and labor, face the same budget and borrowing constraints and insure against future uncertainty via a risk-free one-period asset. Put differently, agents can only self-insure by borrowing and lending at a rate r. Agent's period utility function is additively-separable with the standard constant relative risk aversion (CRRA) over consumption and convex disutility over hours worked. Formally, the functional form of utility is given by:

$$U(c,h) = u(c) - v(h) = \frac{c^{1-\gamma}}{1-\gamma} - \frac{h^{1+\frac{1}{\xi}}}{1+\xi} \tag{3.1}$$

where γ refers to the risk aversion parameter ($\gamma \neq 1$) and ξ is the constant Frisch elasticity of labor supply ($\xi \neq -1$) which can be defined as $\varepsilon = \frac{\partial h/h}{\partial w/w}$ and the Relative Risk Aversion (RRA) is defined as $-\frac{cU_{cc}(c,h)}{U_c(c,h)} = \gamma$.

An agent's individual state consists of their asset holdings, a and their labor productivity z. Given their current state, each agent chooses the quantity of consumption, c, the amount of hours to work h, and their next period asset level a' to maximize the present discount value of their expected utility. The agent's problem is studied using standard dynamic programming techniques. Intuitively, the recursive formulation with the Bellman equation provides a convenient way to express household's problem:

$$V(a,Z) = \max_{\{c,h,a'\}} \left[u(c) - v(h) + \beta \mathbb{E} V(a', z')\right] \tag{3.2}$$

subject to

$$c + a' = (1 + r)a + T + wzh \tag{3.3}$$

$$z' \sim \prod(z'|z) \tag{3.4}$$

$$a' \geq -b \tag{3.5}$$

$$c \geq 0, h \geq 0 \tag{3.6}$$

where the value function $V(a, Z)$ exists, is unique, concave and differentiable in both of its arguments and $\beta \in (0, 1)$ refers to subjective discount factor; variables with the prime notation refer to next period and the expectations operator is defined over the possible realizations of the labor productivity shock: $\mathbb{E}V(a', z') = \sum_{z \in z} \prod(z'|z) V(a', z')$.

Notice that equation 3.3 is the household's budget constraint where z_t denotes idiosyncratic labor productivity shock following a stochastic Markov process with the transition probability matrix (equation 3.4), T are government lump sum transfers while the efficiency wage w and the interest rate r are both determined competitively in equilibrium. In plain words, it is a feasibility condition i.e., household's spending on consumption and investment cannot exceed their current resources.[5] As in standard incomplete markets models, equation 3.5 refers to the individual no-borrowing constraint and equation 3.5 is the nonnegativity condition for consumption and labor respectively.

Solution to the recursive problem from above yields the following intratemporal and intertemporal optimal decision rules:

$$v'(h) = u'(c)zw \tag{3.7}$$

$$u'(c) = \beta \mathbb{E}\left[u'(c')(1 + r)\right] + \lambda \tag{3.8}$$

$$\lambda(a' + b) = 0, \ \lambda \geq 0 \tag{3.9}$$

[5]It is worth stressing that at the stationary equilibrium, factor prices and all aggregate variables are time-invariant because the economy has only idiosyncratic shocks. Therefore, the lack of time subscripts for factor prices. Moreover, in the case of more periods, efficiency wages will include the Markov states for unemployment $\theta = 0$ and employment $\theta = 1$.

where the intratemporal condition (equation 3.7) is the consumption-labor efficiency condition in terms of labor productivity. That is in the margin, the optimal number of hours worked equals the (future) consumption given by marginal labor productivity, whereas the intertemporal margin condition (equation 3.8) states that the subjective discount factor β is the bridge between present and future consumption. Equations 3.8 and 3.9 λ denote the Lagrange multiplier before the borrowing constraint, i.e., households cannot carry negative assets balances to the next period. That is, when the borrowing constraint binds, the optimal choice of next period asset position equals $-b$. Therefore, if the standard no-Ponzi game condition does not hold, then the problem is not well posed and the solution will not yield a maximum because the expected value of earnings is infinite (Aiyagari, 1994).

3.3.3 The Firm

Aggregate output is produced by a competitive representative neoclassical firm that combines the economy-wide supply of capital, K, labor L and public infrastructure K_I. In line with infrastructure literature (see Glomm and Ravikumar (1994), Rioja (2003*a*,*b*), Aisa and Pueyo (2006), Agénor (2008, 2010) and Agénor and Moreno-Dodson (2006) for a detailed discussion on infrastructure channels), the latter enters as a complement of the private capital stock of the economy. In addition, the firm faces constant returns to scale in the production technology and maximizes profits taking factor prices as given. However, infrastructure stock condition Ω is subject to budget failures and information asymmetries; thereby affecting the functioning of public services (e.g., roads/highways networks and/or health services like access to drinking water or garbage disposal through sewage systems, etc) for which private producers make use to derive utility.[6] Additionally, we assume that the provision of infrastructure services (i.e., its flow) are directly proportional to the effective stock of public capital which is a nonrival and nonexcludable good (Agénor, 2009).

Accordingly, the efficiency-adjusted infrastructure stock à la Gibson and Rioja (2017) is ΩK_I (where K_I refers to public infrastructure) and enters into the following production function:

$$y = (\Omega K_I)^{\Phi} K^{\alpha} L^{1-\alpha} \tag{3.10}$$

where $0 < \alpha < 1$, the value of $\Omega \in (0, 1)$ depends on how well the government assigns its infrastructure budget and $\Phi < 1$ is the elasticity of output with respect to the efficient stock of infrastructure K_I. An important question in regards to efficiency is the weight of infrastructure

[6] Others have allowed infrastructure to affect individual utility through an interaction with private leisure (for more details see Chatterjee and Ghosh (2011), Chatterjee and Turnovsky (2012) and Agénor and Canuto (2013).

expenditures in terms of budget transparency. Thus, in our framework the government can reduce budget execution informational (in)efficiencies by investing in e-GP services. The latter relationship is described fully in the next subsection.

Accordingly, the firm chooses aggregate capital and labor and solves the following (static) profit maximization problem:

$$\max_{\{K,L\}} (1-\tau)(\Omega K_I)^{\Phi} K^{\alpha} L^{1-\alpha} - wL - (r+\delta)K \tag{3.11}$$

where τ is the output tax rate, w is the wage rate, r is the rental rate on capital both market clearing; and δ is the depreciation rate of private capital.[7] Solving the firm's problem yields the following standard results:

$$\alpha K^{\alpha-1} L^{1-\alpha} - r + \delta = 0 \longleftrightarrow r = F_K(K,L) - \delta \tag{3.12}$$

and

$$1 - \alpha K^{\alpha} L^{-\alpha} - w = 0 \longleftrightarrow w = F_L(K,L) \tag{3.13}$$

where $F_K(K,L)$ and $F_L(K,L)$ refer to the partial derivative(s) of the production function $F(K,L)$; with respect to physical capital K and effective labor L. In other words, the return on capital rent r and the wage rate, w are both equal to their respective factor's marginal products.

3.3.4 Government

In this simplified economy, the government raises revenue by levying a tax τ on aggregate output. This revenue is used to provide consumption, G, lump sum transfers T and public infrastructure I. Yet, informational asymmetries may also arise due to other factors like corruption, nepotism, rent-seeking activities and/or hidden costs which compromises infrastructure efficiency. Overall, the government faces two options to address the issues: 1) assign part of the budget to preventative maintenance to avoid further depreciation (e.g., potholes in the case of roads/highways) or 2) audit the execution of budget using e-GP tools to improve expenditure efficiency by inviting competitive bids. We rely on the second alternative given higher

[7] Following Gibson and Rioja (2017), the depreciation rate of private capital is also endogenous and has the same functional form as theirs: $\delta = c^{\Phi}\delta_I^{1-\Phi}$ where $c = 0.041$ for the Bangladesh economy (Penn World Table 10.0), $\Phi = 0.5$ and δ_I is the public capital depreciation rate which will be explained in the following subsection. In this way, private capital depreciation rate is less responsive than public capital. Certainly, it might seem unrealistic that e-GP expenditures may affect the durability of private capital. However, a higher transparency on government spending (i.e., a higher ρ) brings more efficiency in private transactions; thereby reducing both δ and δ_I. Therefore, new capital investments are more profitable.

levels of transparency reduces corruption by increasing bidders' access to information on new infrastructure projects. Notwithstanding, in the real world frictions in terms of access to new information as well as political instability may offset the potential benefits of e-GP services.[8]

Government revenues are used to provide public infrastructure: roads/highways services. For simplicity, we assume that a fraction of infrastructure budget (approved the precedent year by a majority of elected representatives) is assigned to e-GP services to improve the efficiency-adjusted condition Ω. To this end, the latter depends on a transparency condition i.e., $\Omega(\sigma)$. In this fashion, public investments could in theory by more productive without incurring in traditional maintenance expenditures. Hence, infrastructure-related expenditures (of GDP) are allocated to new investments, Λ which are also a function of transparency, $\Lambda(\sigma) = \tau_{K_I}$ where Λ refers to roads/highways and σ has the following functional form: $[e + (ab)]^{-\rho}$ where e are public procurement expenditures (of GDP), a the percent of transactions through the use of e-GP over total number of transactions, b is the number of professionals certified on e-GP systems and ρ the percentage of savings value through the use of e-GP systems over total cost estimate.[9] Furthermore, we assume that the government allocates its revenue to infrastructure spendings, τ_{K_I}, consumption τ_G and to lump sum transfers τ_T, where $\tau_{K_I} + \tau_G + \tau_T = \tau$.

Naturally, higher savings from e-GP services can reduce informational gaps as they improve infrastructure condition, so $\Omega'(\sigma) > 0$. In this way, the better the government spends, the lower the depreciation rate of infrastructure as public capital stock extends its utility or "survives" i.e., extends its capacity utilization in time, so $\delta_I(\sigma) < 0$.[10] Additionally, the government is assumed to invest in new infrastructure and e-GP services at a rate that keeps up with depreciation i.e., each dollar covers exactly the amount of old capital which deteriorates. The latter implies that the stock of capital is constant in the steady state. Hence, new infrastructure

[8] For instance, in the presence of rampant corruption and/or nepotism among public officers, government's must make efforts to improve infrastructure provision e.g., grassroots or regular citizens empowered to monitor public officials (Finan et al., 2017) and prevent dishonest behavior (Olken, 2007). Hence, under asymmetric information household's allocations from consumption and labor might change depending on the interactions between public agents and citizens (e.g., a higher probability of briberies among public officers may have a negative impact on private welfare). Another potential source of (in)efficiencies could be the presence of rent-seeking politicians choosing extractive policies motivated by re-election prospects and/or personal ambition. In this case, if citizens stand to gain by replacing the incumbent party, then, distorted taxes in the long-run to finance public infrastructure will be more volatile and potentially persistent (Yared, 2010). We leave those questions for future research.

[9] In the limit, if $\rho = 0$, then the effect of e-GP services vanishes. In other words, if e-GP expenditures do not improve efficiency, then, we assume that transactions on infrastructure are fairly transparent or budget failures are minimal.

[10] Our endogenous depreciation rate is in the spirit of the Keynesian capital utilization rate interpretation as less time is devoted to maintenance expenditures (Greenwood et al., 1988). In this vein, as those authors claim, a partial capacity utilization in the neoclassical model is socially optimal and labor markets always clear. Overall, our interpretation of the depreciation rate is more subtle in the sense that productivity of new investments depend on i) ρ i.e., the percentage of savings value through the use of e-GP; and ii) the status of public capital stock. Thus, in the event of under-maintenance, δ_I can be modelled à la Gibson and Rioja (2017). Although in the presence of corruption and/or nepotism, information on infrastructure projects becomes costly and potential benefits of preventative spendings could be offset. For those reasons we abstract from modelling maintenance expenditures.

investments are given by:

$$\delta_I(\sigma) K_I = \Lambda(\sigma) Y \tag{3.14}$$

where δ_I is the depreciation rate of public infrastructure K_I, Λ is the share of infrastructure expenditures out of the output Y and σ is the transparency condition. If nothing is spent on e-GP services (e), then infrastructure would depreciate fully since the percentage of savings value due the use of e-GP services (ρ) would also be zero. Thus, $\delta_I = 1 - e^{\rho}$ where $\rho > 0$. Overall, the government's total spending is given by:

$$TS = G + T + \delta_I K_I + \sigma Y \tag{3.15}$$

where G is government consumption and T are government transfers. In addition, total revenue is given by:

$$TR = \tau Y \tag{3.16}$$

where τ is a constant tax on output.

At last, we require that the balance condition holds. Therefore, the government's budget constraint is given by

$$TS = TR \tag{3.17}$$

3.3.5 Equilibrium

Definition 1. *A stationary recursive competitive equilibrium for this economy is a value function $v(a, z)$, individual decision rules $c(a, z)$, $h(a, z)$, $a'(a, z)$, a time invariant (stationary) distribution of household over states $\mu(a, z)$, time-invariant factor prices r and w, time-invariant government consumption, taxes, transfers, infrastructure expenditures τ, τ_G, τ_T, τ_{K_I}, σ, Λ and a vector of aggregates, K, K_I, L, C, G, T, TS and TR, such that:*

- *Given prices r and w, government taxes τ and transfers T, and the aggregate stock of physical capital, the value function $V(a, z)$ is the solution to household's recursive optimization problem (3.2) subject to the constraints (3.3), (3.4), (3.5) and (3.6) and $c(a, z)$, $h(a, z)$, $a'(a, z)$ are the optimal decision rules.*

- *Given prices* r *and* w*, the firm maximizes its profits (3.11) so that the first order conditions are satisfied i.e., factor prices are equal to respective marginal products:* $r = F_K(K, L) - \delta$ *and* $w = F_L(K, L)$*.*

- *The stationary distribution* $\mu(a, z)$ *associated with the transition function implied by the optimal decision rule* $a'(a, z)$ *and household's stochastic process* $z' \sim \prod(z'|z)$ *ensuring that* $\mu'(a, z) = \sum_{z \in z} \prod(z'|z) \int_{a:a'=a(a,z)} d_\mu(a, z)$ *holds.*

- *The values of* K*,* L *and* C *are obtained by aggregating over individual decisions:*

  (i) $K = \sum_{z \in z} \int_A a'(a, z) \, d\mu(a, z)$*; where aggregate physical capital demand by the firm equals aggregate total assets holdings by households.*

  (ii) $L = \sum_{z \in z} \int_A z \times h(a, z) \, d\mu(a, z)$*; where aggregate effective labor demand by the firm equals aggregate effective labor supply by households.*

  (iii) $C = \sum_{z \in z} \int_C (a, z) \, d\mu(a, z)$*; where aggregate consumption by the firm equals aggregate consumption by households.*

- *The values of* K_I*,* G*,* T*,* TS *and* TR *are consistent with the government's problem.*

- *Market clears:* $C + \delta K + \delta_I K_I + G + \sigma Y = (\Omega K_I)^{\Phi} K^{\alpha} L^{1-\alpha}$*.*

- *Government balances its budget:* $TS = TR$*.*

Some caveats are worth mentioning. First, we do not target public and private capital stocks rather we model the aggregate capital of the economy jointly because private estimations rely on the perpetual inventory methodology and assume that a fraction of investment what was private in the earliest years (for which there is historical data), was also the fraction for all preceding years. Thus, private capital stock is usually overestimated (Murphy and O'Reilly, 2018). Second, given that infrastructure enters as a complement of the private capital, we provide an initial guess of 0.45 (share of GDP) on the public capital stock in Bangladesh from the IMF Capital Stock Dataset. The data is from IMF Investment and Capital Stock Dataset, 2017.[11]

[11] Available at `https://www.imf.org/external/np/fad/publicinvestment/`.

3.4 Data Sources, Parametrization and Model Solution

3.4.1 Data Sources

The databases used for the calibration analysis performed for Bangladesh in 2018 include the following:

- The average expenditure on paved roads, highways and motorways (of GDP) 2007-2018 from Global Infrastructure Hub (GIH);
- Public procurement expenditures (of the GDP), the percent of transactions through the use of e-GP services over total number of transactions, the number of professionals certified on e-GP systems, percentage of savings value through the use of e-GP systems over total cost estimate in 2018 from Global Public Procurement Database (GPPD);
- Information on the number of days utilized to export, cost to export a container and documents required to export/import by Bangladesh from the LPI database;
- The share of physical capital in production (α), depreciation rate (δ) and and subjective discount rate (β) come from PennWorld Table 10.0 (Feenstra et al., 2015).
- Risk aversion coefficient (γ) is from Gandelman and Hernández-Murillo (2015);
- Frisch elasticity (ζ) for representative agent macroeconomic models comes from Chetty et al. (2011);
- The elasticity of output with respect to efficiency (Φ) comes from Dessus and Herrera (2000);
- Government consumption (of the GDP), transfers and subsidies (of the GDP) 2007-2018 average from WDI;
- Productivity shocks i.e. employment transitions between five employment types: 1) family; 2) casual; 3) government; 4) private; and 5) self-employed (no employees) come from a survey conducted in Bangladesh during 2016 (Gutierrez et al., 2019).

3.4.2 Production and Utility Parameters

The model is calibrated to an annual frequency for Bangladesh in 2018. As regards the share of physical capital in production and the depreciation rate, we rely on Penn World Table 10.0 by Feenstra et al. (2015) and set $\alpha = 0.40$ and $\delta = 0.041$.[12] For the preferences over consumption, the literature on risk aversion reports coefficients predominantly within the 1-1.5 interval for both developed and developing countries (Gandelman and Hernández-Murillo, 2015). In the case of Bangladesh, these estimates are on average 1.30; hence, we set $\gamma = 1.30$. Moreover, following Torul and Öztunalı (2018), we set the value of the Frisch elasticity equal to the multiplicative inverse of the risk aversion parameter: $\zeta = \frac{1}{\gamma}$. The latter is useful to facilitate the computation of the stationary equilibrium when borrowing constraint binds i.e., when $a'(a, z) = -b$. Therefore, $\zeta = 0.77$ which is slightly higher than the proposed value of 0.75 for representative agent macroeconomic models by Chetty et al. (2011) but is acceptable.

For the subjective discount rate β, which reflects the trade-off between future and present consumption, we calculate its value using the data series from the Penn World Table (PWT) 10.0. Hence, in principle, a lower (higher) β value would imply a lower (higher) level of steady state consumption as household's are more (less) impatient. Formally, we feed the Euler equation: $u'(c_t) = \beta \mathbb{E}\left[u'(c_{t+1})(1 + r_{t+1})\right]$ where r_{t+1} satisfies $r_{t+1} = F_K(K_{t+1}L_{t+1}) - \delta_t$ and $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$ where $\gamma = 1.30$ using the capital stock, labor share and the depreciation rate for Bangladesh in 2015.[13] Accordingly, the resultant subjective discount rate is set to $\beta = 0.90$ for our parametrization which is aligned with the standard macroeconomic heterogeneous models for developing countries.[14]

3.4.3 Government and Infrastructure Efficiency Parameters

According to Global Infrastructure Hub (GIH), new investments in Bangladesh (all paved roads, highways and motorways) during 2007-2018 accounted 1.2% (on average) of GDP. For water and sanitization (e.g., water-collection, treatment and processing, transmission and distribution assets including desalination), this represents a meaningful amount of 0.41% of GDP. Nonetheless, the latter should increase by more than one percent point of the GDP (Figure 3.1) given Bangladesh is growing and will no longer be classified as a least developed country by 2026. Hence, we set $\Lambda = 0.012$ for new investments on highways.

[12] The depreciation rate δ will not be explicitly targeted (further details are explained in the following subsection).

[13] To our understanding the year 2015 reflects more accurately the productive structure of Bangladesh because capital stock series vary notably between 2013 and 2018.

[14] Using different discount values results are similar.

As discussed earlier, an important contribution of this paper is to examine how the use of e-GP services reduces informational asymmetries, increases competition among bidders, improves transparency, accountability and better quality audit of new investments. To this end, our model incorporates infrastructures expenditures on roads/highways coupled with e-GP services. We set public procurement expenditures e (of the GDP) along with the percentage of savings value, ρ equal to 0.080 and 0.060 respectively. Accordingly, changes in both (e) and (ρ) will extend the capacity utilization in time of new infrastructure investments through a lower depreciation rate (both private δ and public δ_I). In addition, we use government consumption (G) and transfers (T) data from World Development Indicators (WDI). In the first case, (G) were on average 5.4% while (T) 3.2% of GDP respectively during 2007-2018. Therefore, we set $\tau_G = 0.054$ and $\tau_T = 0.032$.

Furthermore, we compare our efficiency stock condition $\Omega(\sigma)$ with respect to conventional procurement that does not employ e-GP tools. Literature provides evidence that the Logistic Performance Index (LPI) developed by the World Bank is a good proxy of infrastructure quality (Rioja, 2003*b*). This index is constructed from over 5,000 country assessments is by more than 1,000 freight forwarders and logistics professionals worldwide and tracks the quality of roads, ports, railroads and information technology. The LPI is published every two years although it may not be available if a country does not share the information in a particular year. In the case of Bangladesh, the current version covers the years 2007, 2010, 2014, 2016 and 2018 respectively. Overall, the logistics performance of their country and eight other countries are ranked on a scale of 1–5, where 1 represents 'worst' and 5 'top' logistics performers. We follow Gibson and Rioja (2017) and use the LPI from 2007 to 2018 to compare Bangladesh's LPI with the average of top ten infrastructure-quality countries: Germany, Switzerland, Sweden, Austria, Belgium, Japan, Hong Kong, Netherlands, Singapore, and United States. Figure 3.2 shows, the average LPI during 2007-2018 for the above mentioned group of countries is 4 while in Bangladesh 2.6. Therefore, based on the overall scores, it can be inferred that Bangladesh infrastructure efficiency is about 65% of top 10 performers.

Given that the focus of present paper are infrastructure expenditures and e-GP services, we use the functional form for an average estimate of efficiency in terms of transparency $\sigma = [e + (ab)]^{-\rho}$ with e-GP expenditures (of GDP) e, the percent of transactions through the use of e-GP services over total number of transactions a, the number of professionals certified on e-GP systems b and the percentage of savings value through the use of e-GP systems over total cost estimate ρ.[15]

[15] Data comes from Global Public Procurement Database (GPPD).

Our proxy shows an approximative value of 57% for Bangladesh ($\Omega = 0.57$) which is close to the 65% obtained with the LPI overall score. Along the efficiency argument, we set the elasticity of output with respect to efficiency $\Phi = 0.120$ (Dessus and Herrera, 2000). Similarly, we could also consider the long-run elasticities from Bom and Ligthart (2014) because the higher the Φ, the higher the welfare gain of public investments (Rioja, 1999).[16] Table 3.1 contains the complete list of model parameters and data sources.

3.4.4 Labor Productivity Shock Process

We jointly calibrate labor productivity shocks z and its stochastic Markov process $z' \sim \prod(z'|z)$. Literature provides guidance on how to construct the transition probability matrix (see Castaneda et al. (2003) and Kindermann and Krueger (2014)). In the case of incomplete general equilibrium (Bewley-Hugget-Aiyagari) models, states with higher (lower) productivity levels must be persistent because i.e. workers from low productivity jobs are unlikely to switch to higher productivity ones. This assumption is necessary because the above mentioned frameworks cannot amplify wealth dispersion measures based only on the transition probabilities suggested by Aiyagari (1994).

In our model, we use workers information on five type of jobs. This uses information from a survey conducted on Bangladesh during 2016 which includes information on median wages, job-durations, benefits of employments and transitions (Gutierrez et al., 2019). For instance, the median salary of family worker is 7,500 Taka but for a self-employed is 15,000 Taka. Not surprisingly, workers in the government sector earn higher salaries (25,000 Taka), and enjoy higher employment stability in terms of written contracts (92%) and duration (15 years) as well as other social benefits compared to private jobs (e.g., holidays 88%, pensions 82%, etc). However, in emerging and developing countries (EMD) and LDCs, transitions from formal to informal jobs not only involve monetary reasons, but also subjective factors. More qualified workers place also value on personal freedom (e.g., being a boss) and other social aspects like being less exposed to violence, bullying, harassments, discrimination, among others. In this vein, even though workers in the government sector are less likely to experience the aforementioned factors (11%) with respect to self-employed (14%) or private (22%), the probability that a Bangladesh worker change its current job from self-employed to the government is less than 1%

[16] It is worth noting that higher saving costs from e-GP services ρ and a more elastic response of infrastructure with respect to output Φ influence the endogenous depreciation rate. Naturally, we assume that in long-run, the effect of Φ dominates ρ as more growth leads to a better quality service if corruption amongst public officers is minimal and/or taxation effects are not distortive. But as we have explained before, we leave those questions for future research.

while from the private to the government sector is less than 4%. Evidently, the likelihood that a random productive worker decides to move to the public sector is really low.

Accordingly, we set higher probabilities and persistent (immobile) states to the bottom-two productivity jobs: family (low) and casual (low-medium) plus government (medium) which is the reference group for the transition towards low and high productivity jobs. Therefore, private (medium-high) and self-employed (high) jobs will also have very high persistent states. Table 3.2 presents the Markov transition matrix.

3.4.5 Computation Algorithm

To solve the model, we employ the standard tools for computing a stationary recursive equilibrium for incomplete markets models with heterogeneous agents and only idiosyncratic shocks by means of policy iterations and Monte Carlo simulations.

Specifically, we start by guessing values for the real interest rate and plug them into the Euler condition. After we have an initial value for the interest rate, we calculate the real wage associated to the optimal policy decisions and the endogenous depreciation rates (both public and private). Then, using the factor prices we solve household's problem, consumption and the endogenous labor supply while accounting for the borrowing constraint keeping the positive solution so that the non-negativity constraint holds. Finally, given consumption, the endogenous labor and asset values we run simulations to calculate the real interest rate of equilibrium using the last 100 periods. If the resultant real interest rate is not sufficiently close to a certain guess, it is updated and we repeat the process until convergence is achieved. Note that we model infrastructure and aggregate capital jointly because private capital stock estimations through the perpetual inventory method are overestimated. We are interested on measuring infrastructure (in)efficiencies (relative to complete markets)[17] when the government uses e-GP services rather than determining the optimal level of public capital and the transition towards equilibrium. Naturally, the exploration of the transitional dynamic effects are important but this is an area for future research.

3.5 Results

H_{1A} : *Can e-GP services be used as a quantitative measure of infrastructure effectiveness when compared to conventional procurement (i.e. before the 2011 reform)?*

[17] The representative-agent equivalent real business cycle (RBC) model details are in Appendix B.1.

Using information from the GPPD on e-GP expenditure, the percentage of transactions, number of bidders and percentage of savings value that use e-GP systems, we obtain a transparency indicator for Bangladesh in 2018. Results show that new infrastructure expenditures on roads and highways under e-GP systems would achieve 57% efficiency with respect to periods when e-GP was not available or implemented.

We employ the LPI average score in periods before the 2011 e-GP reform and compare Bangladesh with top ten infrastructure-quality countries.[18] Given that the LPI is released every two years, this indicator is limited to the years in which country's report the information. For the pre-reform period, we have valuable information for the years 2007 and 2010. In the first case, conventional procurement effectiveness for Bangladesh was 61% of top worldwide infrastructure performers. In the second case, Bangladesh achieved 68% of infrastructure efficiency when no e-GP was employed. That means that the gap between e-GP systems and conventional procurement is on average 8% after the reform.

Our simple exercise offers two important differences between e-GP systems and conventional procurement. First, a higher intensity of e-GP (i.e. competition) is a necessary but not a sufficient condition to reduce informational asymmetries or the prices paid by governments. Even if e-GP bring prices down, it could lead to the so-called "winner's curse" whereby the lowest price bidder is compelled to renegotiate the contract after the award (Soudry, 2004). Notwithstanding, when used e-GP may decrease the costs of submitting new bids for those not physically present, enabling governments to reduce delays in the completion of new infrastructure projects (20% are on time) and increasing the quality of roads by more than 12% compared compared to conventional procurement where only 5% of projects are finished on time (Lewis-Faupel et al., 2016).

Second, where organisational and institutional factors like corruption and/or nepotism are prevalent among public officers or contractors are physically intimidated by intentionally parties, governments often embark into costly measures to improve infrastructure provision like grassroots organisations (Olken, 2007) to monitor and inform blowing actions and to prevent dishonesty by public officials (Finan et al., 2017). In this manner, e-GP systems through e-auctions may provide an alternative to minimize the informational asymmetries, fraud and other prohibited practises in public procurement projects which are usually regarded as "...one of the most corruption-ridden sectors" (Freedom House, 2010). Hence, policymakers' efforts should be focus on internal policies to improve institutional conditions.

[18] The list of top infrastructure performers in those years was Austria, Belgium, Canada, Germany, Hong Kong, Japan, Luxembourg, Netherlands, Norway, Singapore, Sweden, Switzerland and United Kingdom.

H_{1B} : *Can e-GP transparency gains lead to a better performance of the economy? In other words, if the government reduces informational asymmetries on new bidders, will that imply higher capital stocks (public and private) and/or consumption levels for household's? Will aggregate effects change if markets are incomplete rather than complete?*

Table 3.3 displays the calibration results of aggregate variables and factor prices. At first sight, heterogeneous-agents-models (first row) where households optimally choose the number of hours worked and the government spends on e-GP services generate a higher capital stock (both public and private) at the steady-state than their representative-agent counterpart where agents are ex-ante and ex-post identical (second row). This well-established result is consistent with the well-known *precautionary savings* motive for households under the presence of uninsurable (or partly insurable) idiosyncratic shocks. That is agents save more (i.e. buy assets) than they would if there were no uncertainty. Therefore, the capital stock of the economy increases as a result of insurable or partly shocks (Huggett and Ospina, 2001).

When the government employs e-GP tools to increase the transparency of auctions for new infrastructure projects the mechanism of the economy is simple and general: household's in high (low) productivity jobs remain rich (poor) after a shock (i.e. incomplete markets) than under complete markets. In other words, those with more ability to insure against future uncertainty will buy assets while those with lower ability will stay poor. Furthermore, despite generating equal average productivity levels (0.807) in equilibrium, the performance of the two models is diametrically opposed. Average effective labor is 77% higher in incomplete markets compared to its RBC equivalent and ex-post heterogeneous household's work more hours (71%) with respect to their representative ex-post identical. That is Bangladeshi workers with higher labor productivity draws and asset levels work more hours, generate more output and have higher labor marginal products than their less productive and poorer counterparts in complete markets, but they sacrifice consumption. We provide two explanations for these aggregate results.

First, it is likely that in the long-run only extremely rich (poor) agents with no middle class in between will prevail (Marcet et al., 2006). Therefore, at early stages of development where households have lower average earnings like Bangladesh economy, the lack of mobility between workers with different type of jobs could explain the modest consumption levels under incomplete markets. Hence, if leisure is an inferior good, the precautionary savings and the Aiyagari-Huggett effects (i.e. higher capital-labor ratios) should dominate the ex-post wealth effect because household's with lower ability cannot accumulate assets to insure against future risk. In our case, the inelastic labor supply (borrowed from the macroeconomic literature) which was set equal to the multiplicative inverse of the risk aversion parameter (when the borrowing constraint binds) is higher. This translates into a large output because consumption becomes inelastic relative to hours of labor. From the macroeconomic point of view this means that the sustained growth in per capita income (between 4% to 7%)[19] that the country has experienced during the 2007-2019 was accompanied by improvements on financial intermediation.[20] This paradoxical result may arise when production and/or consumption levels are "too low" (Marcet et al., 2007).[21]

Second, since an increasing competition in e-auctions is a necessary but not a sufficient condition to reduce informational asymmetries, it is possible that the presence of rampant corruption and dishonest behavior among public officials offsets e-GP benefits in terms of additional transparency in new infrastructure projects. Thus, heterogeneous household's may have lower consumption levels compared to identical in complete insurance markets. This result confirms that future uncertainty and lower transparency in government actions enlarges precautionary saving and/or a higher buffer stock of assets leading to lower consumption levels. As explained earlier, our simplified economy does not consider household's optimal response under corruption from public officers, distorted taxation and rent-seeking politicians. Certainly, these frictions might matter for precautionary savings literature given that the empirical evidence is far from being clear (for a more detailed discussion see Carroll et al., 1999). A comprehensive study of infrastructure expenditures and e-GP systems considering household's dynamic decisions when corruption and distorted taxation takes place is a question that we leave for future research.

An Approximation of Inequality in Bangladesh

Infrastructure deficiencies in planning, project preparation in conventional public procurement may conspire to create delays, preventing countries from spending more than two-thirds of public investment allocated to infrastructure in the budget. For instance, budget execution ratios rang from 28% in Benin to 89% in Madagascar with the average being on 66% (Briceño-Garmendia et al., 2009). Additionally, hidden costs in the form taxes, subsidies and/or failure to collect bills in Sub-Saharan can absorb up to 1.8% of GDP on average depending on the sector under analysis: water sanitation 0.5%, power 0.8% and telecommunications 0.3% (Briceño-Garmendia and Klytchnikova, 2006). Therefore, addressing those bottlenecks in low income

[19] Retrieved from World Development Indicators (WDI) `https://data.worldbank.org` on June 1^{th}, 2021.

[20] According to the Financial Development Index Database, in 2011 the financial development index at the time of e-GP reform was 0.21 while at the end of 2019 the country achieved a 0.25 score (i.e. an increase of 18%). Data was retrieved from https://data.imf.org/?sk=F8032E80-B36C-43B1-AC26-493C5B1CD33B on June 10th 2021.

[21] Usually, the empirical literature finds the opposite result i.e. economies with more developed financial systems accumulate more capital achieve higher long-run per capita and productivity growth rates (Levine, 1997).

countries (LICs) where wealth inequality and poverty rates stand at staggering levels, could increase public investments by 50% without any increase in budgeted resources or preventative maintenance expenditures such as highway potholes (Briceño-Garmendia and Klytchnikova, 2006). From a practical point of view, the use e-GP systems for roads and highway spendings in LICs might shed some light on the existence of other channels at work (e.g., corruption) that may prevent countries from achieving a better income distribution.

In the case of Bangladesh, previous studies at a micro level found that the poorest household's benefited the most from road infrastructure expenditures (Khandker et al., 2009). On the macro side, new evidence suggests that public spending reallocations towards education, from health and social protection can have significant growth-promoting effects and may help in reducing income inequality in LICS (Acosta-Ormaechea and Morozumi, 2017). Conversely, social protection and infrastructure spending (keeping fixed the total level of expenditure) transferences towards other types of expenditures tend to increase income inequality (Doumbia and Kinda, 2019).

Notwithstanding, coming-up with inequality measures can be a challenging task because a single dimension method can hardly convey us the actual household's status to the real scenario. This statistical nuisance arises because the major source of statistics i.e., Household Income and Expenditure Surveys (HIES) are not regularly updated and may not contain all the necessary information for our empirical analysis. Consequently, we proceed as follows.

According to recent estimates from the Centre for Policy Dialogue (CPD),[22] wealth inequality (on a scale of 0 to 1) stands at a staggering 0.74 value in 2018 where 1 represents perfect inequality and 0 perfect equality. Therefore, we calibrate the model to match that level of wealth.

However, an approximative estimate to the top 10% wealth decile ratio in Bangladesh is even more difficult. On the one side, a valid strategy would be to use the wealth concentration data provided by Credit Suisse (2018) and extrapolate the missing years. Even though the latter reports information for the majority of countries, decile ratios for the wealthiest (e.g., top 5% or top 10%) in Bangladesh are not available neither in the current nor former editions. On the other side, the Wealth Databook of that same institution displays the Gini coefficient of the within distribution along with the top share of adults wealth in US$. Hence, in light of the absence of empirical estimates, we set a (conservative) target value equal to 67.80% for the top 10% of wealth in 2018. In this line, standard growth theory predicts that as countries develop, inequality should decrease in tandem. Therefore, one would expect that our conservative target

[22] Available at `http://www.cpd.org.bd`.

value might be overestimated for a country posting a 5.0% to 8.0% GDP growth rate and a per income growth of 4% to 7% on average during 2007 to 2018 (WDI). Nonetheless, as the National Board of Revenue in Bangladesh (NBR) explains, the share of personal income to total tax revenue is still low due to large compliance problems - with less than 1.0% of the population being under the income tax net. Accordingly, the country has had the highest rise in its ultra-wealthy population surpassing any other country in the world during the 2012-17 period (17.3% growth on average). Not surprisingly, a recent report from the China-based Hurun Global in 2017 named one Bangladeshi businessman on its global rich list with an estimated fortune of USD 1.3 billion.[23]

Likewise, income inequality estimates suffer from two major problems. First, data truncation i.e., household surveys are partially representative for the poorest t per cent. Thus, non parametric methods are mandatory to ameliorate the upper tail bias which clearly overstates inequality measures (Jorda and Niño-Zarazúa, 2019). Second, literature provides evidence that labor informality can influence (to some extent) income inequality measures. More precisely, employment transitions from formal jobs to informal ones are more likely to occur in developing and emerging (EMD) and LDCs —where one-third and two-thirds of economic activity are registered under the informal economy— (see Bosch and Maloney (2010), Goldberg and Pavcnik (2003), Paz (2014), Arias et al. (2018), Gutierrez et al. (2019), Ulyssea (2020), among others) due to infrastructure conditions, quality of institutions, degree of tax-enforcements, social benefits provided by governments and the functioning of credit markets.[24] In terms of calibration, matching income tails based on employment transitions of Bangladeshi workers represents a challenge given workers heterogeneity with respect to jobs personal satisfaction and governments performance. For those reasons, we abstract from matching income inequality measures.

Last but not least, for the Gini consumption we set its value at 0.32. Data comes from the World Income Inequality Database (WIID), Household Income and Expenditure Survey (HIES) 2016-17 and World Bank estimates revised up to the latest available year with information (2019). It is noteworthy that non-durable consumption estimates based on microdata must be taken with caution due to the presence of intra-household inequality (i.e. heterogeneity among

[23]The outstanding performance of the super rich people in Bangladesh is not that far from global trends where the bottom part of the wealth distribution has been growing approximately 5% per year since 1987 while wealth middle class growth was almost half (2.5% on average) and the wealthiest class experienced growth rates of 7-8% per year according to Forbes. Overall, these stylized facts suggest two things: 1) financial globalization makes increasingly hard to measure top wealth. Thus, empirical estimates may underestimate the real amount of wealth; 2) in spite of decreasing global wealth trends (mostly driven by China) within countries, wealth concentration is still rising (Zucman, 2019).

[24]Informality is no longer considered in a strictly binary sense (labor market segmentation), i.e., social benefits (holidays, pensions, long-term contracts, etc) are just another variable within workers economic calculus (e.g., personal freedom) and some of them may choose to leave the formal economy in spite of losing it.

family members). In other words, each member allocation does not necessarily have the same share of consumption nor the resources. Notwithstanding, for a country case analysis like the present paper those issues do not necessarily compromise the calibration performance.

Table 3.4 reports the model performance against Bangladesh data. On the one hand, results display an endogenous wealth distribution (given by the Gini coefficient) of 0.79. Therefore, our baseline model slightly overestimates Bangladesh wealth concentration with respect to CPD estimates in 2018 (0.74). The latter seems reasonable in light of the latest report from China-based Hurun Global and Forbes global trends for the super-rich business men. Therefore, this fact confirms the presence of an increasing and unequal wealth distribution in Bangladesh where the majority of workers have little or no assets at all and a small pool of individuals concentrate almost all wealth generated by the country.

On the other hand, the model generates a top 10 wealth decile ratio of 73.5% which mimics the conservative target we assigned to Bangladesh in 2018, 67.8% closely. In this vein, there are at least two factors which may explain a higher concentration of wealth in the top 10 decile. First, lack of tax compliance results in poor tax efforts, i.e., the absence of stringent rules in terms of tax collections reduces the state's capacity to reinvest revenues from the wealthiest class into social protection and unprivileged sectors. For instance, Bangladesh spent about 1% of GDP on social protection and only 0.10 US$ a day per capita (PPP) in transfers for the poorest quintile which means that more than 46% of people in extreme poor conditions (less than US$ at a day) did not receiving social protection in 2016 (World Bank Atlas of Social Protection Indicators of Resilience and Equity (ASPIRE)). Second, according to HIES 2016-17 data about 70% of the beneficiaries could not be reached due to mismatches i.e., inclusions and exclusions errors of the targeted segment of population (i.e. the bottom 50 percent). Certainly, in LDCs like Bangladesh these bottlenecks in social spending programs coupled with dishonest behavior or nepotism amongst public officers and rampant corruption, can also explain the lack of effectiveness of fiscal redistribution policies and the increasing wealth inequality experienced by the country during the last years.

Finally, the model mimics non-durable consumption inequality in Bangladesh with a 0.25 Gini with respect to the 0.32 value in 2016 according to latest estimates from WIID, HIES and WB. Although, results indicate a minor difference in total household consumption levels, (urban and rural). A possible explanation is that welfare conditions may have been improved from 2016 to 2018 as a result of the economic growth acceleration, higher educational attainment rates and increasing female labor participation (Rahman et al., 2013). Although, these findings must be considered with caution as intra-household consumption inequality tends to be pervasive and poverty-targeting policies on per-capita consumption measures miss a significant fraction of poor individuals. Thus, one-third of the population below the World Bank (WB) extreme poverty line are classified as nonpoor using the household per-capita consumption measure (Brown et al., 2021).

Accordingly, the proposed model with infrastructure expenditures where governments employ e-GP services delivers inequality measures consistent to Bangladesh transition from LDC to lower-middle-income country status. Evidently, the increasing and staggering wealth inequality that the country has been experiencing in the last years is dramatic as many poor workers must live with less than US$ 2 dollars at day. In this line, we sustain that perfect competition together with the development of credit markets may not reduce inequality nor favor household's poor condition as industries like the the ready-made garment (RMG) employ mostly unskill informal workers. Rather, a higher coverage in social spending programs coupled with more enforcement controls to reduce corruption and mismatches i.e., inclusions and exclusions errors of the targeted segment of population is the best action for Bangladesh policymakers.

3.6 Concluding Remarks

This paper examines whether the use of e-GP technologies (in the aftermath of the 2011 reform) in new infrastructure projects implied a better macroeconomic performance for Bangladesh. To this end, we first construct a transparency indicator for the year 2018 and compare its value to conventional procurement measures (given by the LPI) the years before the 2011 reform (2007 and 2010). We use a novel data on e-GP expenditure, the percentage of transactions, number of bidders and percentage of savings value that use e-GP tools and World Bank Logistic Performance Index (LPI) for conventional procurement. Results indicate that the gap between e-GP systems and the LPI is on average 8% in the years after the reform.

To account for the macroeconomics effects when governments employ e-GP systems for new infrastructure investments, we calibrate a general equilibrium model with heterogeneous agents in incomplete markets including an endogenous labor supply decision. Results show that the well-established precautionary saving applies i.e. in the presence of uncertainty the capital stock of the economy increases as household's with high ability accumulate assets. In addition, the average effective labor is 77% higher in incomplete markets compared to complete markets and ex-post heterogeneous household's work more hours (41%) with respect to their representative ex-post identical. That is Bangladeshi workers with higher productivity and asset levels work more hours, generate more output and have higher labor marginal products than their less productive and poorer counterparts in complete markets, but they sacrifice consumption. We offer two explanations for these results. In the long-run only extremely rich (poor) agents with no middle class in between will prevail. This is consistent to early stages of development or transitions between low- and middle-income economies with an inelastic labor supply accompanied by a better developed financial intermediation provided by the country. Conversely, it is quite likely that the presence of rampant corruption and dishonest behavior among public officials offsets e-GP benefits in terms of additional transparency in new infrastructure projects. Hence, increasing competition in e-auctions may not be sufficient to provide higher savings to workers with lower ability to smooth out consumption in the uncertainty state (e.g., unemployment). Finally, the model fits particularly well the increasing wealth inequality and mimics closely the non-durable consumption inequality.

In light of the findings, improving the access to new information on e-auctions and simplifying, and harmonizing documents, streamlining procedures, and using e-GP tools will help to reduce informational asymmetries in new infrastructure projects and will improve the performance of economy. From an institutional perspective, policymaker' efforts must focus on internal policies to improve institutional conditions like control of corruption as well as initiating steps to enhance the capacity of the e-GP data center and improve cyber-security. In this line, the US$ 40 approved contract by the World Bank to help Bangladesh increase its coverage of e-GP systems to respond to the COVID-19 challenges is without a doubt an important step towards a higher quality of infrastructure investments as it promotes fiscal space (i.e. efficient use and allocation of resources) and stimulates private sector growth increasing citizens confidence in government and private sector competitiveness through better delivery service like tendering and software support for those not physically present, enabling governments to reduce delays in the completion of new public projects.

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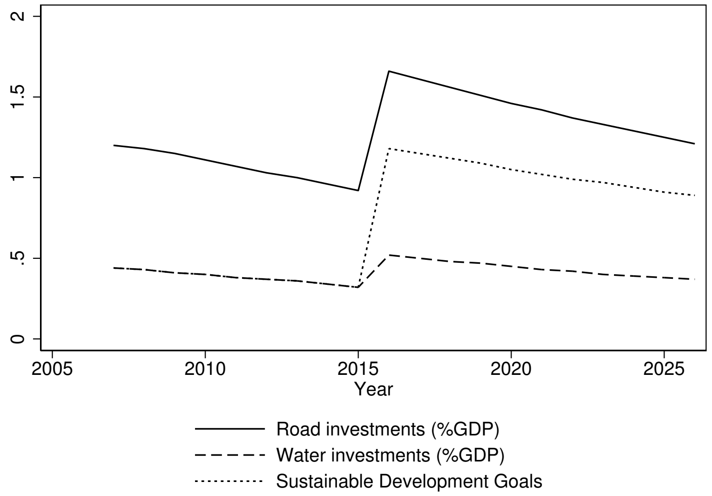
Figures

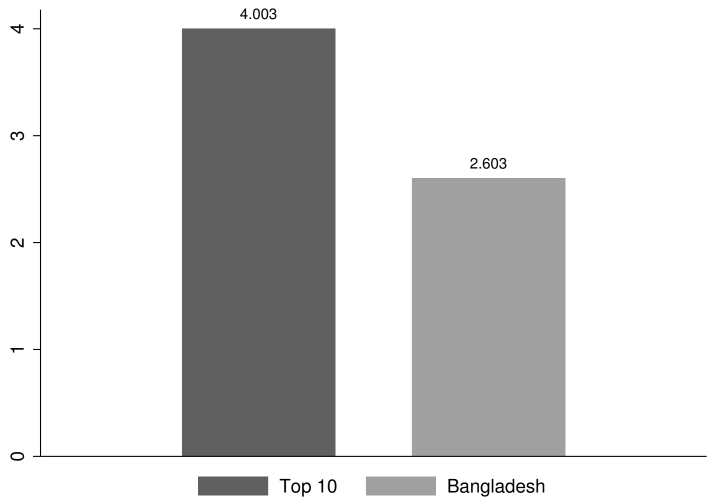
FIGURE 3.1: Infrastructure expenditures and Sustainable Development Goals

Bangladesh 2007-2026



Road investments include all paved roads, highways and motorways while Water investments encompass water-collection, treatment and processing, transmission and distribution assets (including desalination) and Sustainable Development Goals (SDGs) refer to required investments in the latter sector on Bangladesh transition from LDC to lower-middle-income country status (originally for 2024 but postponed to 2026 due to the Covid-19 outbreak) Projections are based on Oxford Economics' forecast of GDP growth rate in Bangladesh from 2016 to 2040. Source: Global Infrastructure Hub.

FIGURE 3.2: Logistic performance index average scores 2007-2018



Note: The overall score is based on efficiency of customs clearance process, quality of trade- and transport-related infrastructure, ease of arranging competitively priced shipments, quality of logistics services, ability to track and trace consignments, and frequency with which shipments reach the consignee within the scheduled time. Top 10 countries are Germany, Switzerland, Sweden, Austria, Belgium, Japan, Hong Kong, Netherlands, Singapore, and United States. Source: author own calculations based on World Bank.

Tables

TABLE 3.1: Model Parameters

Parameter	Symbol	Value	Source
Capital's Share in Production[a]	α	0.40	Penn World Table 10.0 (PWT)
Subjective Discount Rate[b]	β	0.90	Penn World Table 10.0 (PWT)
Relative Risk Aversion	γ	1.30	Gandelman and Hernández-Murillo (2015)
Frisch Elasticity of Labor Supply	ζ	0.77	Chetty et al. (2011)
Borrowing Constraint	b	0.000	Aiyagari (1994)
Infrastructure Investment-GDP ratio	Λ	0.012	Global Infrastructure Hub (GIH)
Public procurement expenditures (percentage of GDP)	e	0.080	Global Public Procurement Database (GPPD)
e-GP services (percentage of savings value)	ρ	0.060	Global Public Procurement Database (GPPD)
Government Consumption-GDP ratio	τ_G	0.054	World Development Indicators (WDI)
Transfers-GDP ratio[c]	τ_T	0.032	World Development Indicators (WDI)
Elasticity of Y w.r.t. Infrastructure[d]	Φ	0.120	Dessus and Herrera (2000)

Notes:
a. Using previous versions of PWT, Gollin (2002) shows that adjusted factor shares for self-employment income are remarkably constant both in time and across countries; and thus, capital shares are around 0.30. Yet, the global labor share has been declining significantly since the early 1980s —for different industries and across countries— due to the lower price of investment goods and capital augmenting technologies (Karabarbounis and Neiman, 2014). In the case of Bangladesh, the reported share of capital income by PWT 10.0 was 0.30 on average until 2013; although the series vary notably after that year. Thus, we believe that a capital income share of 0.40 and a labor share of 0.60 in 2015 from PWT reflects more appropriately the current productive structure of the country. Moreover, the latter are relatively close to the ones reported on Bangladesh Household Income and Expenditure Survey (2010, 2015) data which is 0.65 on average.
b. For developing countries, Ahmed et al. (2012) find that the discount factor of most of the developing countries is relatively similar to that of developed ones.
c. Subsidies and other transfers in local units currency relative to the U.S dollar are reported until the year 2016. Hence, we extrapolate it until 2018 in a most conservative way and use Bangladesh GDP to come up with a relative measure.
d. Suggested for LDCs.

TABLE 3.2: Productivity Shocks

	$z_1 = 0.85$	$z_2 = 0.90$	$z_3 = 1.00$	$z_4 = 1.25$	$z_5 = 3.00$
	z_1	z_2	z_3	z_4	z_5
z_1	0.600	0.350	0.050	0.000	0.000
z_2	0.350	0.600	0.050	0.000	0.000
z_3	0.000	0.200	0.800	0.000	0.000
z_4	0.000	0.000	0.000	0.700	0.300
z_5	0.000	0.000	0.000	0.200	0.800

Note: Our earnings transition matrix is based on five employment categories (family, casual, government, private, and self-employed) from a worker survey in Bangladesh during 2016.

Table 3.3: Aggregate Variables and Factor Prices

Model	K	H	Z	L	Y	C	r	w	rK	wL
Aiyagari (w/ roads)	1.075	1.019	0.807	0.793	0.897	0.680	0.103	0.719	0.111	0.570
RBC (w/ roads)	0.689	0.575	0.807	0.464	0.299	1.111	0.111	0.705	0.077	0.327

Table 3.4: Model's fit versus Data

Parameter	Measure	Data	Model (w/ roads)
Wealth	Gini Coefficient	0.74	0.79
	Top 10%	67.80%	73.35%
Consumption	Gini Coefficient	0.32	0.25

Data sources: Centre for Policy Dialogue (CPD) for the wealth Gini coefficient; Credit Suisse (2018) for the Top 10% (approximatively due to lack of estimates); World Income Inequality Database (WIID), Household Income and Expenditure Survey (HIES) 2016-17 and World Bank estimates revised up to the latest available year (2019) with information for the consumption Gini coefficient.

Appendix: Chapter II

A.1 Variable Definitions

Infrastructure

- Public infrastructure: capital outlays of highway spending which includes the following items: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. Source: The Government Finance Database (Pierson et al., 2015).

- Private infrastructure: non-residential historical construction expenditures. Data comes from U.S Census.

Price deflators

- State price index (table 3.9.4) from Bureau of Economic Analysis (BEA).

- Consumer Price Index for All Urban Consumers (CPI-U) 1982-84=100 (adjusted) from the Bureau of Labor Statistics (BLS).

Gross Domestic Product

- Real Gross Domestic Product by State at constant prices 2012. To construct this variable, we take the GDP on each state for all industries (Millions of current dollars) and deflate it by the CPI-U 2012. The Bureau of Economic Analysis (BEA) data were based on the SIC industrial classification codes until 1997 and the NAICS codes thereafter. Hence, to account that discontinuity on the GDP series, I use the average of the two nominal GDPs for that year and then apply the price deflator.

State taxes

- R&D tax-credits: Rate of research and development tax credit for a given year. Data comes from The W.E. Upjohn Institute for Employment Research.

Urban controls

- Average temperatures in January and July. National Centers for Environmental Information.
- Population density. We construct this variable dividing the land area (Sq. mi.) by the state population using the Census State Area Metropolitan Measurements and Internal Point Coordinates.

High-tech industries

For our main analysis, we regard the following disaggregated industries as high-tech sectors:

- Computer and Electronic Product Manufacturing (NAICS 334). Industries or group of establishments that manufacture computers, computer peripherals, communications equipment, and similar electronic products, and establishments that manufacture components for such products. The Computer and Electronic Product Manufacturing industries have been combined in the hierarchy of NAICS because of the economic significance they have attained. Their rapid growth suggests that they will become even more important to the economies of all three North American countries in the future, and in addition their manufacturing processes are fundamentally different from the manufacturing processes of other machinery and equipment. The design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production technologies of the Computer and Electronic Product Manufacturing subsector. Convergence of technology motivates this NAICS subsector. Digitalization of sound recording, for example, causes both the medium (the compact disc) and the equipment to resemble the technologies for recording, storing, transmitting, and manipulating data. Communications technology and equipment have been converging with computer technology.

- Publishing Industries (except Internet) (NAICS 511). Industries in the Publishing Industries (except Internet) subsector group establishments engaged in the publishing of newspapers, magazines, other periodicals, and books, as well as directory and mailing list and software publishing. In general, these establishments, which are known as publishers, issue copies of works for which they usually possess copyright.

- Motion Picture and Sound Recording Industries (NAICS 512). Industries or group of establishments involved in the production and distribution of motion pictures and sound recordings. While producers and distributors of motion pictures and sound recordings issue works for sale as traditional publishers do, the processes are sufficiently different to warrant placing establishments engaged in these activities in a separate subsector. Production is typically a complex process that involves several distinct types of establishments that are engaged in activities, such as contracting with performers, creating the film or sound content, and providing technical postproduction services. Film distribution is often to exhibitors, such as theaters and broadcasters, rather than through the wholesale and retail distribution chain. When the product is in a mass-produced form, NAICS treats production and distribution as the major economic activity as it does in the Publishing Industries (except Internet) subsector, rather than as a subsidiary activity to the manufacture of such products. This subsector does not include establishments primarily engaged in the wholesale distribution of video and sound recordings, such as compact discs and audio tapes; these establishments are included in the Wholesale Trade sector. Reproduction of video and sound recordings that is carried out separately from establishments engaged in production and distribution is treated in NAICS as a manufacturing activity.

- Broadcasting (except Internet) (NAICS 515). Industries or group of establishments that create content or acquire the right to distribute content and subsequently broadcast the content. The industry groups (Radio and Television Broadcasting and Cable and Other Subscription Programming) are based on differences in the methods of communication and the nature of services provided. The Radio and Television Broadcasting industry group includes establishments that operate broadcasting studios and facilities for over-the-air or satellite delivery of radio and television programs of entertainment, news, talk, and the like. These establishments are often engaged in the production and purchase of programs and generating revenues from the sale of air time to advertisers and from donations, subsidies, and/or the sale of programs. The Cable and Other Subscription Programming industry group includes establishments operating studios and facilities for the broadcasting of programs that are typically narrowcast in nature (limited format, such as news, sports, education, and youth-oriented programming) on a subscription or fee basis.

- Telecommunications (NAICS 517). Industries or group of establishments that provide telecommunications and the services related to that activity (e.g., telephony, including Voice over Internet Protocol (VoIP); cable and satellite television distribution services; Internet access; telecommunications reselling services).

- Data Processing, Hosting, and Related Services (NAICS 518). Industries or group of establishments that provide the infrastructure for hosting and/or data processing services.

- Other Information Services (NAICS 519). Industries or group of establishments supplying information, storing and providing access to information, searching and retrieving information, operating Web sites that use search engines to allow for searching information on the Internet, or publishing and/or broadcasting content exclusively on the Internet. The main components of the subsector are news syndicates, libraries, archives, exclusive Internet publishing and/or broadcasting, and Web search portals.

- Professional, Scientific, and Technical Services (NAICS 541). Industries or group of establishments engaged in processes where human capital is the major input. These establishments make available the knowledge and skills of their employees, often on an assignment basis, where an individual or team is responsible for the delivery of services to the client. The individual industries of this subsector are defined on the basis of the particular expertise and training of the services provider.

For a details of each industry see the 2017 manual description `https://www.census.gov/eos/www/naics/`

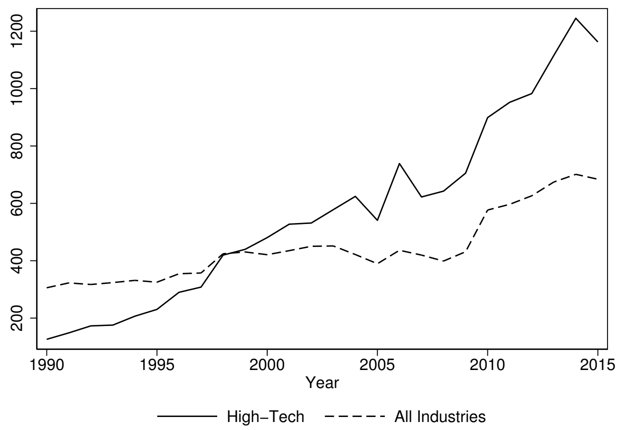
Innovation

- State policy innovation and policy diffusion (see appendix A3 for more details).

- Patents & scientific citations by industry. Data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017).
  - For instance in Figure A.1.1 the average number of patents and scientific citations is presented. At first sight, we appreciate that high-tech industries had a better performance in terms of innovation outcomes with respect to others. More precisely, a visual inspection of the data show that patents in the former sector rises after the 2000 with respect to all industries. Overall, the average number of patents during 1990-2015 were 577 reaching to a maximum of 19,852 while in latter patents accounted on average 443 with a peak of 4,378.
  - In overall terms after 1995, a group of industries leaded by Computer & electronic product manufacturing, increased their innovation activities. More precisely, the average number of patents and citations in the former group was 6.3 whereas in the latter 1.8. (Figure A.1.2)
  - Moreover, in Figure A.1.3 we can observe that the distribution of high-tech patents has been decreasing in the last decade. A possible explanation is that the pace of fruitful innovations is reaching to an end and/or the economy is running-out of fruitful ideas (Gordon, 2012). This fact is corroborated in the Figure A.1.4 where the dispersion of the percentile gap in terms of top and bottom innovations was left skewed in the early 90's. However, after 1995 that difference start narrowing and ended-up at minimal levels in 2015. In other words, the marginal contribution of each new scientific patent is small regardless the type of innovator (top and bottom).

FIGURE A.1.1: Average number of patents and citations

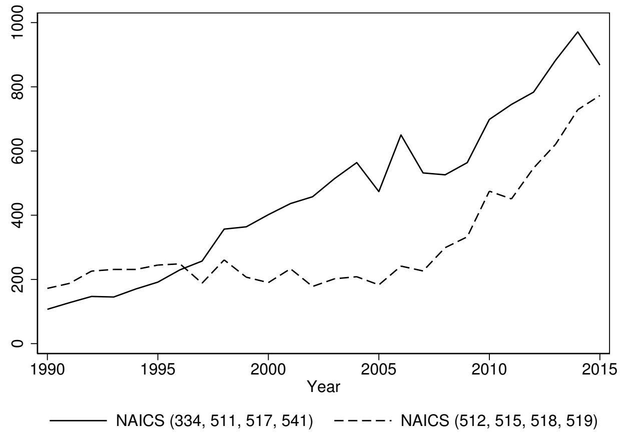
U.S public firms: 1990-2015



Note: High-tech industries (software and telecommunications) were collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334 (Computer & electronic product manufacturing); 511 (Publishing industries except internet); 512 (Motion picture & sound recording industries); 515 (Broadcasting except internet); 517 (Telecommunications); 518 (Data processing, hosting, & related services); 519 (Other information services); 541 (Professional, scientific, & technical services). All industries encompass: retail & construction, healthcare, manufacturing (including mining and utilities), and others (finance, transportation warehousing, agriculture and others (mostly services). For more details see Appendix A.1.

FIGURE A.1.2: Average number of patents and citations by value added

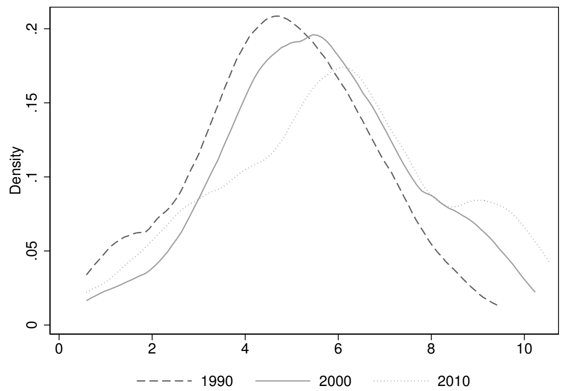
High-tech industries: 1990-2015



Note: Data comes from COMPUSTAT (public firms). High-tech industries (software and telecommunications) at three-digit North American Industry Classification Structure (NAICS) level: 334 (Computer & electronic product manufacturing); 511 (Publishing industries except internet); 512 (Motion picture & sound recording industries); 515 (Broadcasting except internet); 517 (Telecommunications); 518 (Data processing, hosting, & related services); 519 (Other information services); 541 (Professional, scientific, & technical services). For more details see Appendix A.1.

FIGURE A.1.3: Densities of innovation gap

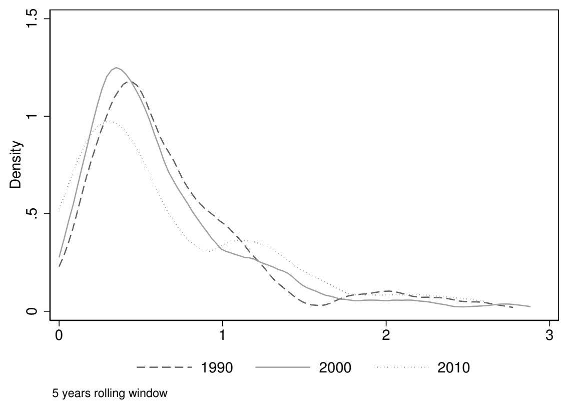
High-tech industries: 1990-2015



Note: This figure presents kernel density functions of the percentile gap (i.e., 90^{th} and 10^{th}) of patents and scientific citations by decades. Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017). Analytical weights (average) aggregate value share (AV) of U.S public firms in 2001 are considered Crouzet and Eberly (2018), Hall (2018). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively (for more details see Appendix A.1). The labor market indicators subsection contains a brief description of each sector. For a clear visual inspection, patents are rescaled per 100,000 population and transformed into logarithms. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE A.1.4: Densities of innovation gap dispersion

High-tech industries: 1990-2015

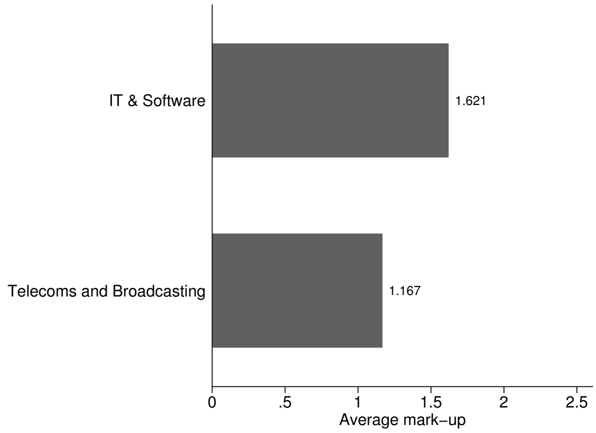


Note: This figure presents kernel density functions of the percentile gap dispersion (i.e., 90^{th} and 10^{th} standard deviation) of patents and scientific citations by decades. Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017). Analytical weights (average) share of aggregate value (AV) of U.S public firms in 2001 are considered Crouzet and Eberly (2018), Hall (2018). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively (for more details see Appendix A.1). For a clear visual inspection, patents are rescaled per 100,000 population and transformed into logarithms. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). To avoid business cycles rolling windows are included. Source: author own calculations.

Market Power & Share of Aggregate Value

FIGURE A.1.5: Average markup broad industries

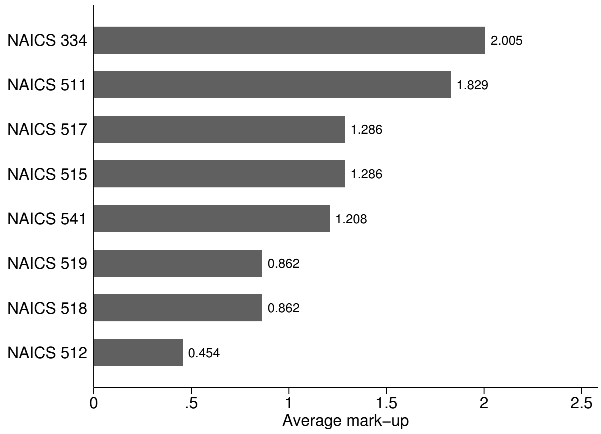
High-tech industries: 1990-2015



Note: Average markups of public U.S firms (COMPUSTAT) were calculated following Crouzet and Eberly (2018) and Hall (2018) methodology. Information and Technology Software at three-digit North American Industry Classification Structure (NAICS) and KLEMS level regard 334, 511, 518, 519 and 541. Whereas Telecommunication and Broadcasting include 512, 515 and 517 respectively (for more details see Appendix A.1). The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE A.1.6: Average markup by subsector

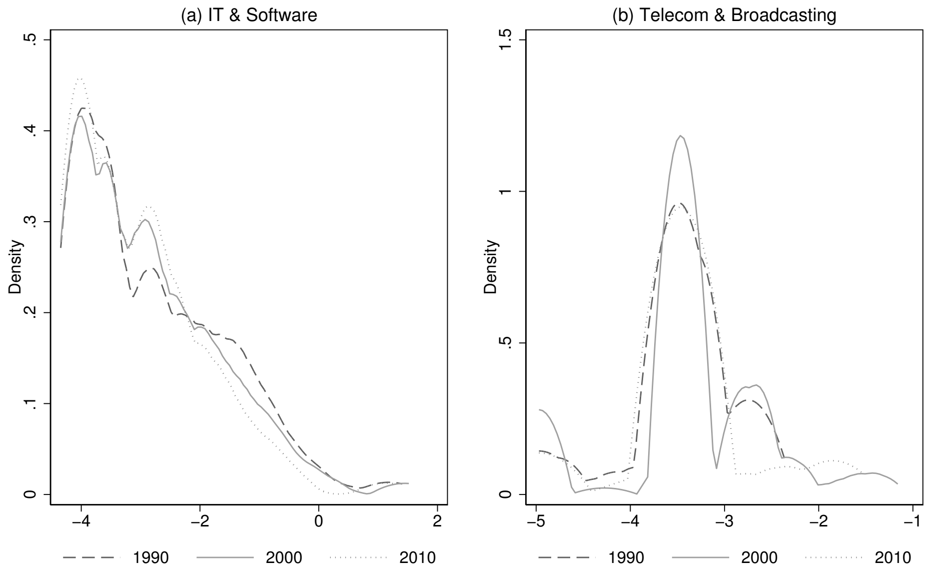
High-tech industries: 1990-2015



Note: Average markups of public U.S firms (COMPUSTAT) were calculated following Crouzet and Eberly (2018) and Hall (2018) methodology. High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively (for more details see Appendix A.1). The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

FIGURE A.1.7: Densities of aggregate value share by broad sector

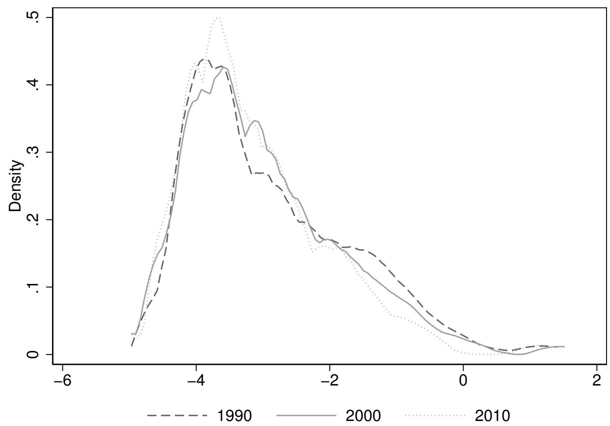
High-tech industries: 1990-2015



Note: This figure presents kernel density functions of (average) share of aggregate value (AV) for U.S public firms in 2001 by decades. In doing so, we follow Crouzet and Eberly (2018) and Hall (2018) methodology methodology. Information and Technology Software at three-digit North American Industry Classification Structure (NAICS) and KLEMS level regard 334, 511, 518, 519 and 541. Whereas Telecommunication and Broadcasting include 512, 515 and 517 respectively (see Appendix A.1). The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). For a clear visual inspection the share of aggregate value was transformed into logarithms. Source: author own calculations.

FIGURE A.1.8: Densities of broad aggregate value share

High-tech industries: 1990-2015

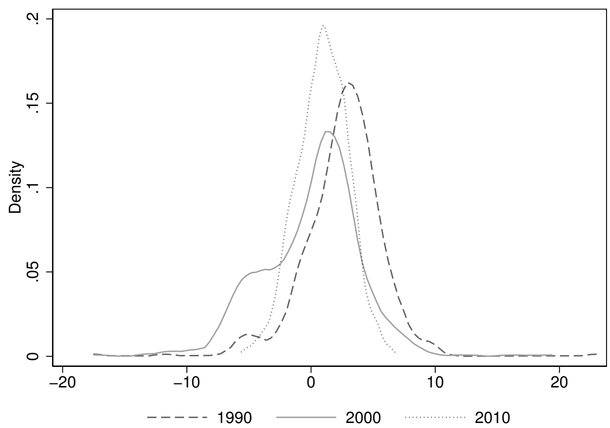


Note: This figure presents kernel density functions of (average) share of aggregate value (AV) for U.S public firms in 2001 by decades. In doing so, we follow Crouzet and Eberly (2018) and Hall (2018) methodology methodology. High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively (see Appendix A.1). The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). For a clear visual inspection the share of aggregate value was transformed into logarithms. Source: author own calculations.

Labor Market Indicators

- Employment
  - Annual average of monthly employment levels for a given year. Quarterly Census of Employment and Wages (QCEW).

FIGURE A.1.9: Densities of high-tech employment: 1990-2015



Note: This figure presents kernel density functions for high-tech employment growth rates by decades. Data is from Quarterly Census of Employment & Wages (QCEW). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively (see Appendix A.1). The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

- Wages
  - Annual (real) wage levels are based on the 12-monthly employment levels (i.e., payroll). Quarterly Census of Employment and Wages (QCEW). Nominal payrolls were deflated using the BLS consumer price index CPI-U (2012=100), normalized by state population to control for business cycle effects and rescaled into logarithms (explain more an include also wage-gap).
  - Moreover, given the fact that QCEW universe does not include all firms, we complement payroll data with County Business Patterns (CBP). In this line, we make use of the concordance weights from SIC97 to NAICS12 (Eckert et al., 2020).
  - Dummy variable equal to 1 if state minimum wages are higher than federal ones. Source: Historical minimum wages by states (Vaghul and Zipperer, 2016).

Complementary data

- Education attainment
  - High school attainment is the total number of high school graduates divided by the total state population.*
  - College attainment is the total number of college graduates divided by the total state population.*
- Civilian non-institutional employment, unemployment rate and population by states. Data comes from the Bureau of Labor Statistics (BLS).

* indicates that for some years the number of graduates is limited to the population 14/15 years or older. Data comes from Frank (2009).

Appropriation Committee

Total number of senators by state Congressional committee assignments (1947-1992) and (1993-2017) (Stewart and Nelson, 2005, Stewart III and Woon, 2017). Each senator is counted considering the date of appointment and the date of termination. Moreover, in order to have a straightforward interpretation, we construct a dummy variable in the following way: 0 is the State does not have any member on the appropriation committee, 1 (if at least has one), 2 (if at least has two) and 3 if it has three senators or more. Remark: some states have no representatives (e.g. Wyoming) while in some years, other states have been imputed a value of 0 given the fact that no member was present on that period.

Institutions

- Economic Freedom of North America (EFNA).

1. Government Spending

A. General Consumption Expenditures by Government as a Percentage of Income General consumption expenditure is defined as total expenditures minus transfers to persons, transfers to businesses, transfers to other governments, and interest on public debt. Spending on fixed capital is also excluded

B. Transfers and Subsidies as a Percentage of Income Transfers and subsidies include transfers to persons and businesses like welfare payments, grants, agricultural assistance, food-stamp payments (US), housing assistance. Foreign aid is excluded.

C. Insurance and Retirement Payments as a Percentage of Income Payments by Employment Insurance, Workers Compensation, and various pension plans are included in this component.

2. Tax distortion

A. Income and Payroll Tax Revenue as a Percentage of Income Income and Payroll Tax Revenue is defined as the sum of personal income taxes, corporate income taxes, and payroll taxes used to fund social-insurance schemes (i.e., employment insurance, Workers Compensation, and various pension plans).

B. Top Marginal Income Tax Rate and the Income Threshold at Which It Applies (see pp. 57-61)

C. Property Tax and Other Taxes as a Percentage of Income Property and Other Tax revenue consists of total tax revenue minus income and sales tax revenues (which are already included in 2A and 2D). Natural resource royalties and severance taxes are not included in this component.

D. Sales Tax Revenue as a Percentage of Income Sales tax revenue includes revenue from all sales and gross receipts taxes (including excise taxes and value-added taxes).

3. Labor market freedom

Ai. Minimum Wage Legislation: This component was calculated as minimum wage multiplied by 2,080, which is the full-time equivalent measure of work hours per year (52 weeks multiplied by 40 hours per week) as a percentage of per-capita income.

Aii. Government Employment as a Percentage of Total State/Provincial Employment: Government employment includes public servants as well as those employed by government business enterprises. Military employment is excluded.

Aiii. Union Density: Determine the relationship between unionization and public policy, other than the level of government employment, which is captured in 3Aii. We regressed union density on the size of the government sector.

Recessions

- (1990-1991). This downturn primarily affected the Northeast and the Mid–Atlantic regions, including Pennsylvania, Maryland, Delaware, and Virginia. Compared to other previous periods (e.g. early 1980s'), the energy-producing states are among those which experienced an increase in employment during this period—along with many of the states further West, such as Arizona, Nevada, Utah, Idaho and Hawaii.

- (2001). For this downturn, there was little variation in employment growth rates. Indeed, it ranged from -2.20% to 2.24% and at the same time, energy-producing states did not out-perform with respect to the rest of the economy.

- (2008-2010). This is the most severe recession (after the 29' downturn) because only six states experienced employment growth during this period. Particularly, its negative impact was mostly into the Sun Belt states (Arizona, Nevada, Florida) as well as the Rust Belt states of Michigan, Ohio and Indiana. Conversely, employment grew on the energy-producing states like Alaska, Texas, Oklahoma, Louisiana and North Dakota increased between 2008 and 2010. In broader terms, employment growth performance in the Northeast region fared comparatively well with respect to the other ones.

A.2 Innovativeness and Diffusion Networks

Policy Descriptions

Education

- Teacher certification-elementary. First year applied: 1930. Source: Walker
- Creation of council on the arts. First year applied: 1936. Source: Walker
- Maintaining segregated educational systems for out of state study. First year applied: 1927. Source: Boehmke-Skinner
- In what year does the state require elementary school teachers to hold a degree?. First year applied: 1930. Source: Caughey-Warshaw
- Educational television. First year applied: 1951. Source: Walker
- Agreement for using libraries on an interstate basis. First year applied: 1957. Source: Karch
- Facilitates movement of education professionals across states. First year applied: 1962. Source: Karch
- Information center on education matters. First year applied: 1965. Source: Karch
- Provides that a student loan is enforceable against debtor. First year applied: 1970. Source: Uniform Law
- Does the state ban corporal punishment in schools?. First year applied: 1970. Source: Caughey-Warshaw
- Allowed to enroll in college while in high school. First year applied: 1976. Source: Lacy
- Strategic planning for education. First year applied: 1976. Source: Boehmke-Skinner
- Statewide transfer agreement (higher education). First year applied: 1976. Source: Lacy
- State Establishment of post-secondary student record data system. First year applied: 1976. Source: Lacy
- Restructuring of state higher education governance structures. First year applied: 1985. Source: Lacy
- High school exit exams. First year applied: 1976. Source: Boehmke-Skinner

- Access to college placement exams and remediation before college. First year applied: 1978. Source: Lacy
- Performance based funding. First year applied: 1979. Source: Lacy
- States adopting performance based funding for higher education. First year applied: 1979. Source: Other
- State eminent scholar policy. First year applied: 1983. Source: Lacy
- Centralization of tuition control. First year applied: 1985. Source: Lacy
- State sponsored prepaid tuition plans. First year applied: 1986. Source: Lacy
- State adoption of prepaid tuition. First year applied: 1986. Source: Other
- School choice. First year applied: 1987. Source: Boehmke-Skinner
- States allowing for less central control over tuition setting. First year applied: 1987. Source: Lacy
- College savings plan. First year applied: 1988. Source: Lacy
- Comprehensive remediation reform. First year applied: 1988. Source: Lacy
- Delivery Of remediation. First year applied: 1988. Source: Lacy
- College tuition saving plans. First year applied: 1988. Source: Other
- Community college bachelor's degree. First year applied: 1989. Source: Lacy
- Remedial credits counting or non-counting towards graduation and full-time status. First year applied: 1989. Source: Lacy
- Charter schools. First year applied: 1991. Source: Boehmke-Skinner
- Merit based aid program. First year applied: 1993. Source: Lacy
- Merit system for states (post 1993). First year applied: 1993. Source: Doyle
- Universal pre-K education. First year applied: 1995. Source: Curran
- Limits for remediation (time, credit hours, etc.) and punishment of unsuccessful students in the developmental education. First year applied: 1996. Source: Lacy
- Remediation expanded or limited to certain sectors of higher education. First year applied: 1996. Source: Lacy

- Accountability (such as reporting rates Of enrollment and outcomes, performance based funding). First year applied: 1996. Source: Lacy
- Placement policies (placement examination, changes to placement criteria. First year applied: 1997. Source: Lacy
- Teaching of native American History Made Mandatory or optional. First year applied: 1999. Source: Other
- Instate tuition for undocumented immigrants. First year applied: 2001. Source: Lacy
- State voucher funding for higher education. First year applied: 2003. Source: Lacy
- Remedial credits counting toward financial aid. First year applied: 2004. Source: Lacy
- Instate tuition for veterans. First year applied: 2006. Source: Lacy
- Financial support or reduction of the support for remediation (cost). First year applied: 2006. Source: Lacy
- Helps military children transfer academic credits between institutions. First year applied: 2008. Source: Karch
- Governs relations among student athletes, athlete agents, and educational institutions. First year applied: 2011. Source: Uniform Law
- Revision of previous law- expands definition of student and athlete. First year applied: 2016. Source: Uniform Law

Energy

- Compact on reducing waste of oil and gas. First year applied: 1935. Source: Karch
- Does the State approve for a local tax credit for residential solar installations? First year applied: 1975. Source: Caughey-Warshaw
- Does the State have a tax credit for residential solar installations? First year applied: 1975. Source: Caughey-Warshaw
- Billing credit for renewable energy users who add electricity to the grid. First year applied: 1983. Source: Other
- Setting renewable energy standards. First year applied: 1983. Source: Other

- Residential tax credits for renewable energy systems. First year applied: 1990. Source: Matisoff
- Residential tax credits for efficiency. First year applied: 1990. Source: Matisoff
- Implement on-site renewable energy generation. First year applied: 1990. Source: Matisoff
- Tax credits for renewable technologies. First year applied: 1990. Source: Matisoff
- Environmental building standards. First year applied: 1991. Source: Matisoff
- Electricity deregulation. First year applied: 1996. Source: Boehmke-Skinner
- Does the State have a public benefit fund for renewable energy and energy efficiency? First year applied: 1996. Source: Caughey-Warshaw
- Restructuring electricity system. First year applied: 1996. Source: Other
- Renewable portfolio standard. First year applied: 1997. Source: Matisoff

Environment

- Soil conservation districts- enabling legislation. First year applied: 1937. Source: Walker
- Does the State have an air pollution control act (Pre-Clean Air Act)? First year applied: 1947. Source: Caughey-Warshaw
- Does the state have an endangered species act? First year applied: 1969. Source: Caughey-Warshaw
- Does the state have its own version of the Federal National Environmental Policy Act? First year applied: 1970. Source: Caughey-Warshaw
- Container-deposit legislation. First year applied: 1971. Source: Boehmke-Skinner
- Does the State require a deposit on bottles paid by the consumer and refunded when the consumer recycles? First year applied: 1972. Source: Caughey-Warshaw
- Strategic planning for environmental protection. First year applied: 1978. Source: Boehmke-Skinner
- Overcomes procedural obstacles that prevent a pollution victim in one State or province from seeking enforceable remedies in the State or province where the pollution originated. First year applied: 1983. Source: Uniform Law

- Provides a means through which states can participate in a reciprocal program to enforce wildlife citations. First year applied: 1989. Source: Karch
- Collect public benefit fund. First year applied: 1996. Source: Matisoff
- Does the State have a recycling program for electronic waste? First year applied: 2000. Source: Caughey-Warshaw
- Does the State adopt California's car emissions standards (which are more stringent than the federal level)? First year applied: 2003. Source: Caughey-Warshaw
- Does the state have a binding cap on greenhouse gas emissions in the utility sector? First year applied: 2006. Source: Caughey-Warshaw
- State e-waste disposal programs. First year applied: 2003. Source: Mallinson
- Provides clear rules for a perpetual real estate interest: An environmental covenant to regulate the use of brownfields when real estate is transferred from one owner to another. First year applied: 2004. Source: Uniform Law

Domestic Commerce Policies

- Creation of State advertising commission. First year applied: 1925. Source: Walker
- Protect The Purchaser of real estate where there is a binding contract of sale. First year applied: 1937. Source: Uniform Law
- Bilateral/Mutual aid for disasters. First year applied: 1951. Source: Karch
- Does the State have a lottery?. First year applied: 1964. Source: Caughey-Warshaw
- Lottery. First year applied: 1964. Source: Boehmke-Skinner
- Regulation on promotional sale of land. First year applied: 1967. Source: Uniform Law
- Prohibit unfair or deceptive trade practices and unfair competition. First year applied: 1968. Source: Uniform Law
- Regulates business partnerships in the US. First year applied: 1968. Source: Uniform Law
- Regulates offer and sale of securities. First year applied: 1968. Source: Uniform Law
- Modernizes trust and estate law. First year applied: 1968. Source: Uniform Law

- Regulates abandonment Of property. First year applied: 1968. Source: Uniform Law
- Provides standards for credit transactions entered into by individuals who purchase, use, maintain, and dispose of products and services. First year applied: 1969. Source: Uniform Law
- Helps make regulation of business partnerships uniform between states. First year applied: 1969. Source: Uniform Law
- Governs inheritance and decedents' estates. First year applied: 1971. Source: Uniform Law
- Crystallize the best elements of contemporary federal and State regulation of consumer sales practices. First year applied: 1972. Source: Uniform Law
- Provides guidance on investment decisions and endowment expenditures. First year applied: 1973. Source: Uniform Law
- Regulating secure transactions in personal property. First year applied: 1973. Source: Uniform Law
- Provides a statutory framework that governs secured transactions –transactions which involve the granting of credit secured by personal property–. First year applied: 1973. Source: Uniform Law
- Does the State allow casinos? First year applied: 1977. Source Caughey-Warshaw
- Permits the formation of limited liability companies. First year applied: 1979. Source: Uniform Law
- Required registration of beer keg purchases. First year applied: 1980. Source: Sheprd
- Codify the common law with proper clarification of rights and remedies in relation to a trade secret. First year applied: 1980. Source: Uniform Law
- Bankruptcy law. First year applied: 1982. Source: Uniform Law
- Classifies a category of transfers as fraudulent to creditors and provides creditors with a remedy for such transfers. First year applied: 1985. Source: Uniform Law
- Agreement for aid across states in event of disaster/emergency. First year applied: 1985. Source: Karch

- Regulates passage of assets if multiple people die within short period. First year applied: 1985. Source: Uniform Law
- Governs transfer of investment securities. First year applied: 1987. Source: Uniform Law
- Compact for assistance in event of earthquake. First year applied: 1988. Source: Karch
- Regulates offer and sale of securities. First year applied: 1988. Source: Uniform Law
- Provides States with a legal framework for any transaction, Regardless Of Form, That Creates A Lease. First year applied: 1988 Source: Uniform Law
- Provides non-probate transfer of specifically registered investment securities from owner to named beneficiaries at owner's death. First year applied: 1990. Source: Uniform Law
- Includes electronic transfers in regulation of fund transfers. First year applied: 1990. Source: Uniform Law
- Repeal legislation of Ucc Article 6 (Bulk Sales Law). First year applied: 1990. Source: Uniform Law
- Revise Ucc Article 6 (Bulk Sales Law). First year applied: 1990. Source: Uniform Law
- Regulates payment system. First year applied: 1990. Source: Uniform Law
- Reflects "A Modern Portfolio Theory" and "Total Return" approach to the exercise of fiduciary investment discretion. First year applied: 1991. Source: Uniform Law
- Attempts to standardize negotiable instruments in States. First year applied: 1991. Source: Uniform Law
- Regulates passage of assets if multiple people die within short period. First year applied: 1992. Source: Uniform Law
- Individual development accounts. First year applied: 1993. Source: Boehmke-Skinner
- Encourages banks and credit unions to offer pod (Pay On Death) and agency (convenience) account forms for use by persons desiring some, but not all, incidents of joint accounts. First year applied: 1993. Source: Uniform Law
- Helps make regulation of business partnerships uniform between States. First year applied: 1993. Source: Uniform Law
- Governs All unincorporated non-profit associations that are formed or operate in a state. First year applied: 1993. Source: Uniform Law

- Mutual assistance between states in emergency or disaster situations. First year applied: 1995. Source: Karch
- Managing insolvent interstate insurance companies. First year applied: 1995. Source: Karch
- Revises commercial codes, specifically transfers of securities. First year applied: 1995. Source: Uniform Law
- Regulates abandonment of property. First year applied: 1995. Source: Uniform Law
- Regulates payment system. First year applied: 1996. Source: Uniform Law
- Permits the formation of limited liability companies. First year applied: 1997. Source: Uniform Law
- Banning alcohol sales on Sundays. First year applied: 1998. Sourte: Sheprd
- Restrictions on displaying credit card numbers on sales receipts. First year applied: 1999. Source: Boehmke-Skinner
- Establishes uniform requirements for licensing of participants in live racing with Pari-Mutuel Wagering. First year applied: 2000 Source: Karch
- Limits credit agencies from issuing a credit report without consumer consent. First year applied: 2001. Source: Boehmke-Skinner
- Assure that meaningful and accurate disclosure of lease terms is provided to consumers before entering into a contract. First year applied: 2002. Source: Uniform Law
- Compact regulating insurance policies. First year applied: 2003. Source: Karch
- Regulates business partnerships in the US. First year applied: 2003. Source: Uniform Law
- Regulates offer and sale of securities. First year applied: 2003. Source: Uniform Law
- Provides definitions and general provisions which, in the absence of conflicting provisions. First year applied: 2003. Source: Uniform Law
- Attempts to standardize negotiable instruments in States. First year applied: 2003. Source: Uniform Law
- Regulates storage and shipment of tangible goods. First year applied: 2004. Source: Uniform Law

- Regulating mortgage holder rights. First year applied: 2005. Source: Uniform Law
- Governing national administration of debt counselling and management in a fair and effective way. First year applied: 2006. Source: Uniform Law
- Establishes a comprehensive statutory model for the creation, perfection, and enforcement of security interests in rents. First year applied: 2007. Source: Uniform Law
- Allows state governments during a declared emergency to give reciprocity to other States licenses on emergency service providers. First year applied: 2007. Source: Uniform Law
- Allow conversion of one kind of business organization to another, or the merger of two or more business organizations into one organization. First year applied: 2007. Source: Uniform Law
- Addresses the cooperative form of business. First year applied: 2008. Source: Uniform Law
- Permits The formation of limited liability companies. First year applied: 2008. Source: Uniform Law
- Governs inheritance and decedents' estates. First year applied: 2009. Source: Uniform Law
- Governs all unincorporated non-profit associations that are formed or operate in a state. First year applied: 2009. Source: Uniform Law
- Address purchase of life insurance trusts. First year applied: 2011. Source: Uniform Law
- Allows for designated beneficiary to automatically receive property transfer at owner's death. First year applied: 2011. Source: Uniform Law
- Provides the rules governing any transaction (other than a finance lease) that couples a debt with a creditor. First year applied: 2011. Source: Uniform Law
- Governing National Administration of Debt Counselling And Management in a fair and effective Way. (2011 Update). First year applied:2012: Source: Uniform Law
- Governs the use of statutory trusts as a mode of business organization. First year applied: 2012. Source: Uniform Law
- Amendments provide that article 4A Does apply to a remittance transfer that is not an electronic funds transfer under the Federal Electronic Funds Transfer Act. First year applied: 2012. Source: Uniform Law

- Extends power of fiduciary. First year applied: 2014. Source: Uniform Law
- Strengthens creditor protections. First year applied: 2015. Source: Uniform Law
- Extends Power of fiduciary- revision Of 2014 law only passed by Delaware. First year applied: 2016. Source: Uniform Law
- Non judicial method for modifying Irrevocable Trust. First year applied: 2016. Source: Uniform Law
- Provides a standard set of rules for courts to apply for real estate receivership. First year applied: 2017. Source: Uniform Law

Housing

- Zoning in cities-enabling legislation. First year applied: 1913. Source: Walker
- Public housing-enabling legislation. First year applied: 1933. Source: Walker
- Planning and development agencies. First year applied: 1935. Source: Walker
- Does the State provide direct aid for urban housing? First year applied: 1939. Source: Caughey-Warshaw
- Urban renewal-enabling legislation. First year applied: 1941. Source: Walker
- Does the State have urban renewal areas?. First year applied: 1945. Source: Caughey-Warshaw
- Does State prohibit the Passage Of rent control laws in its cities or municipalities? First year applied: 1950. Source: Caughey-Warshaw
- Building code adoption. First year applied: 1953. Source: Min Hee Go
- Fair housing-private housing. First year applied: 1959. Source: Walker
- Requiring local government to coordinate growth management. First year applied: 1961. Source: Boehmke-Skinner
- Does a State have a law authorizing or requiring growth-management planning? First year applied: 1961. Source: Caughey-Warshaw
- Codify best practices in leasing housing. First year applied: 1972. Source: Uniform Law
- Provisions for creation, management, and termination of condominium associations. First year applied: 1980. Source: Uniform Law

- State enterprise zones. First year applied: 1981. Source: Boehmke-Skinner
- Provides comprehensive legislation governing the critical phases of cooperative development: Creation, Financing, Management, And Termination. First year applied: 1982. Source: Uniform Law
- Governs the formation, management, and termination of common interest communities (1982 Version). First year applied: 1983. Source: Uniform Law
- Covers creation, management, and termination of time shares. First year applied: 1983. Source: Uniform Law
- Regulating condemnation of property on behalf of private and public entities. First year applied: 1985. Source: Uniform Law
- Ownership of real estate means ownership of interests and rights in an actual piece of geography. First year applied: 1987. Source: Uniform Law
- Creates Commission to create uniform rules and regulations governing the design and construction of industrialized/modular buildings First year applied: 1990. Source: Karch
- Governs the formation, management, and termination of common interest communities (1994 Version). First year applied: 1995. Source: Uniform Law
- Comprehensive provisions for Creating, managing, and terminating planned community developments. First year applied: 1997. Source: Uniform Law
- Governs the formation, management, and termination of common interest communities (2008 Version). First year applied: 2009. Source: Uniform Law
- Governs the formation, management, and termination of common interest communities. First year applied: 2010. Source: Uniform Law

Labor

- Beautician licensing. First year applied: 1914. Source: Walker
- Minimum wage law. First year applied: 1915. Source: Walker
- Real estate brokers- Licensing. First year applied: 1917. Source: Walker
- Integrated bar. First year applied: 1921. Source: Walker

- Does the State have a pension system? First year applied: 1935. Source: Caughey-Warshaw
- Does the State have a labor relations Act patterned after Wagner Act? First year applied: 1937. Source: Caughey-Warshaw
- Does the State have a labor relations Act patterned after Taft-Hartley? First year applied: 1939. Source: Caughey-Warshaw
- Migratory labor committee. First year applied: 1943. Source: Walker
- Does the State have A Minimum Wage For Men? First year applied: 1944. Source: Caughey-Warshaw
- Does the State have right to work legislation? First year applied: 1944. Source: Caughey-Warshaw
- Fair employment laws. First year applied: 1945. Source: Boehmke-Skinner
- Does the State have a temporary disability insurance program? First year applied: 1945. Source: Caughey-Warshaw
- Seasonal agricultural labor standards. First year applied: 1945. Source: Walker
- Retainers agreement. Firs year applied: 1957. Source: Walker
- Does The State have collective bargaining rights for local teachers? First year applied: 1960. Source: Caughey-Warshaw
- Does The State have collective bargaining rights for State government employees? First year applied: 1966. Source: Caughey-Warshaw
- Is The State's minimum wage above the federal level? First year applied: 1968. Source: Caughey-Warshaw

Macroeconomics

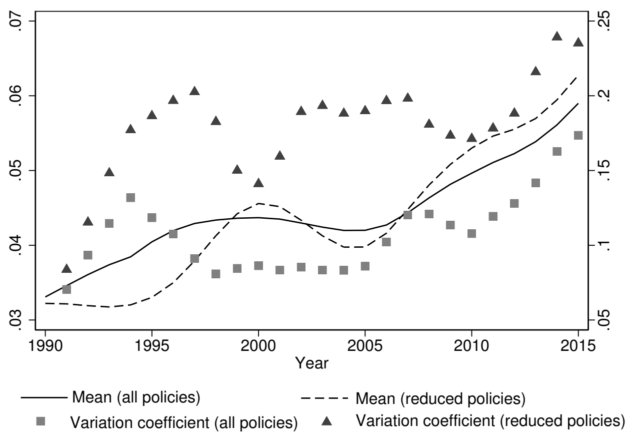
- State income tax. First year applied: 1916. Source: Boehmke-Skinner
- Divides income between states for tax purposes when living/working in multiple states. First year applied: 1950. Source: Uniform Law
- Creates system for taxing multistate taxpayers. First year applied: 1967. Source: Karch

- Allows federal tax liens to be filed in an office designated by the law of the State in which the property subject to the lien is situated. First year applied: 1968. Source: Uniform Law
- Interstate pest control compact. First year applied: 1968. Source: Boehmke-Skinner
- Allow every sort of disclaimer, including those that are useful for tax planning purposes. First year applied: 1974. Source: Uniform Law
- Tax and expenditure limits (spending limits). First year applied: 1976. Source: Boehmke-Skinner
- Strategic planning for economic development. First year applied: 1981. Source: Boehmke-Skinner
- Strategic planning for revenue. First year applied: 1981. Source: Boehmke-Skinner
- State credits for research and development. First year applied: 1982. Source: Lacy
- Does the state have an earned income tax credit? First year applied: 1988. Source: Caughey-Warshaw
- Corporate incentives. First year applied: 1990. Source: Matisoff
- Film tax credits. First year applied: 1992. Source: Mallinson
- Allow every sort of disclaimer, including those that are useful for tax planning purposes. First year applied: 2000. Source: Uniform Law
- Is there a state estate eax? First year applied: 2009. Source: Caughey-Warshaw
- Eliminates duplicative and inconsistent tax and regulatory requirements among the states. First year applied: 2011. Source: Karch
- Seek passage of balanced budget amendment to US Constitution. First year applied: 2014. Source: Karch
- Articulate and confirm the role of the State attorney general in protecting charitable assets. First year applied: 2014. Source: Uniform Law

State Policy Innovation Scores

The dynamic policy diffusion employed in this paper is based on the the static policy innovativeness scores described in Boehmke and Skinner (2012). More precisely, on the one hand, static scores available include a modified version of Walker's (1969) innovation score; a standardized score; a standardized score that accounts for right censoring; and a rate score. On the other hand, a dynamic version of the rate score is available for arbitrary time intervals as well as a smoothed version of the dynamic annual rate score. In our case, given that we are interested on few policies, we regard the dynamic smooth score as our innovation and policy diffusion index. Despite the fact that the average mean of the index among U.S regions remains more or less unchanged, its variation coefficient depicts a great variability, specially for the 2000-2005 period (17.3) reaching a maximum of 21.3 in the aftermath of the Great Recession period. As a result, we hypothesize that public policies may have a substantial and heterogeneous impact over regional labor markets.

FIGURE A.2.1: Innovation and policy diffusion scores: 1990-2015



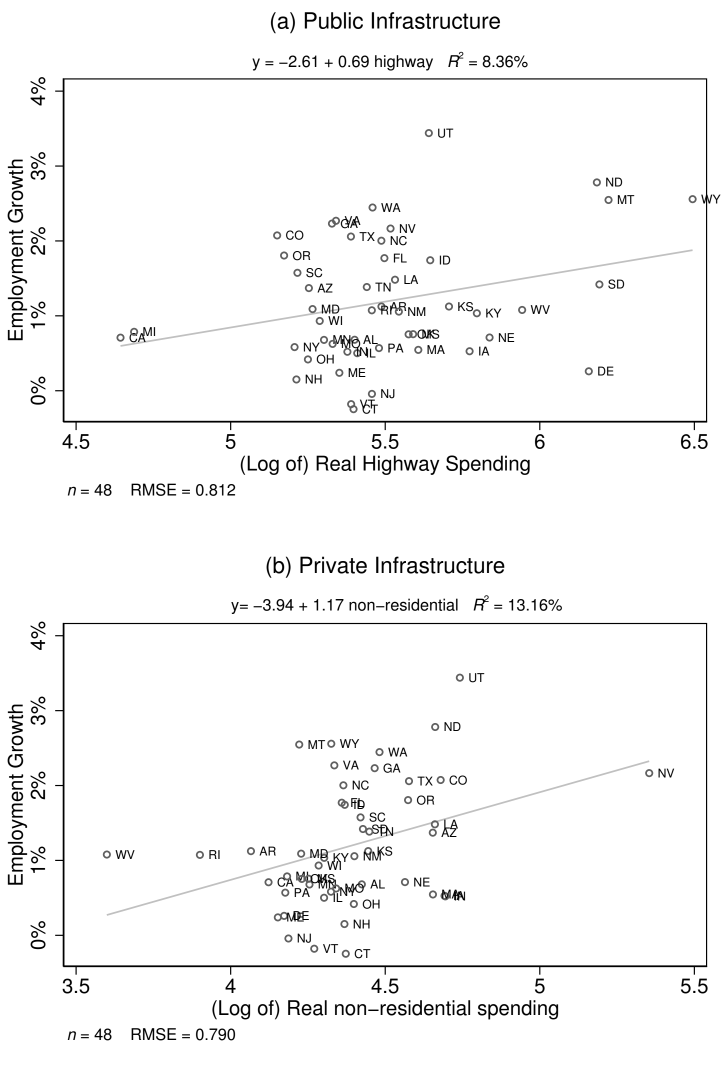
Note: The smooth reduced score includes 204 public policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Whereas the total score encompass the reduced policies as well as civil rights, health, agriculture, immigration, law & crime, social welfare, defence, technology, foreign trade, transportation, international affairs, government operation and public lands. Overall, U.S regional policies account a total of 728 policies.

A.3 Additional Figures

Cross-sectional plots

FIGURE A.3.1: Infrastructure and employment (cross-sectional plots)

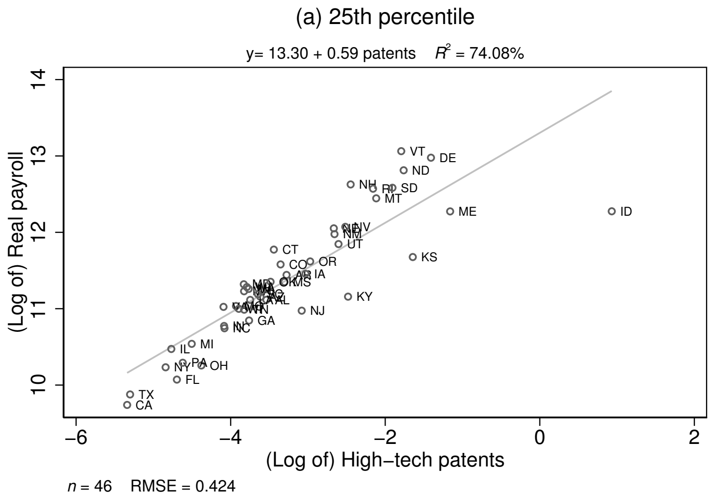
High-tech industries: 1990-2015

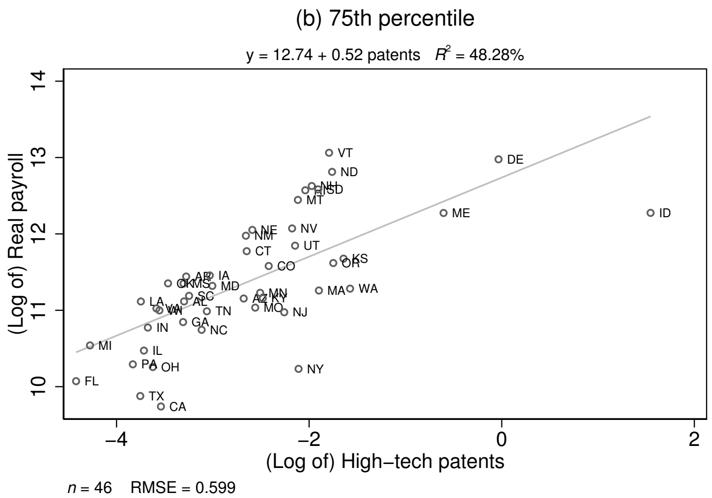


Note: Real public infrastructure is defined as the capital outlays of highway spending which includes the following items: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. Its real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) which takes into account the price of investment goods (table 3.9.4). Conversely, private infrastructure (private non-residential spending) was deflated using the BLS consumer price index CPI-U (2012=100). Employment data (line) is from Quarterly Census of Employment & Wages (QCEW). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 receptively. Appendix A.2 contains a brief description of each industry. The analysis excludes the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). In order to get a clear visual inspection of the data, both variables were transformed into logarithms. Source: author own calculations.

FIGURE A.3.2: Wages and innovation: by quartiles (cross-sectional plots)

High-tech industries: 1990-2015

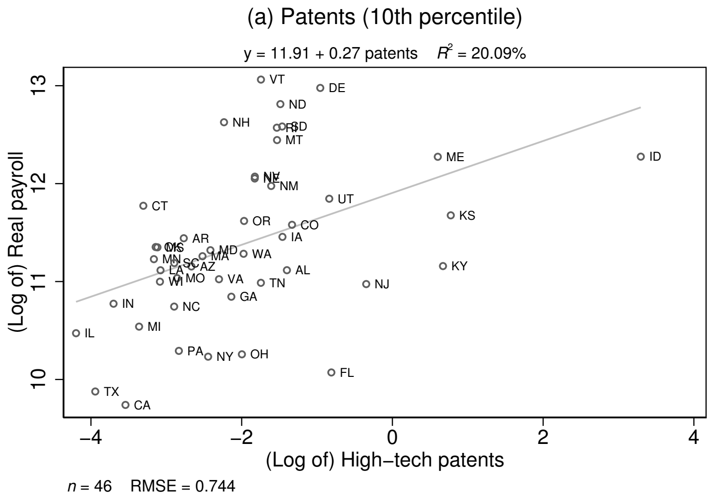


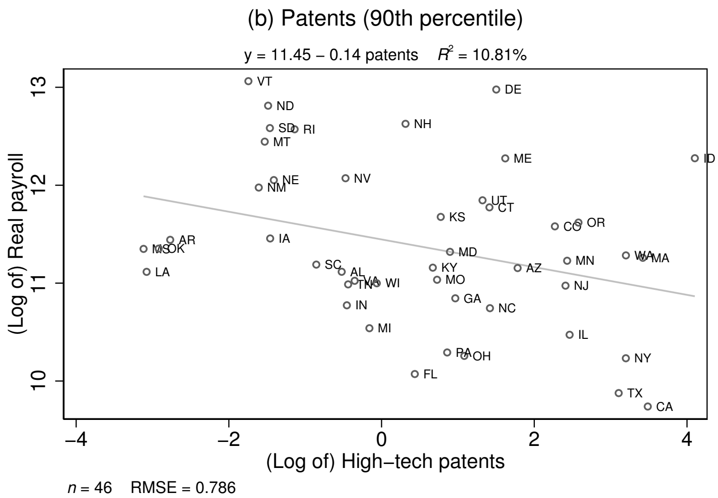


Note: Wage bill (i.e., annual payroll) data comes from the Quarterly Census of Employment & Wages (QCEW). Nominal values were deflated using the BLS consumer price index CPI-U (2012=100) and rescaled into logarithms. Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017). Percentiles are constructed as the weighted sum of the share of aggregate value (AV) of U.S public firms in 2001 Crouzet and Eberly (2018), Hall (2018). High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.2 contains a brief description of each industry. For a clear visual inspection, patents are rescaled per 100,000 population and transformed into logarithms. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

Figure A.3.3: Wages and innovation: by percentiles (cross-sectional plots)

High-tech industries: 1990-2015

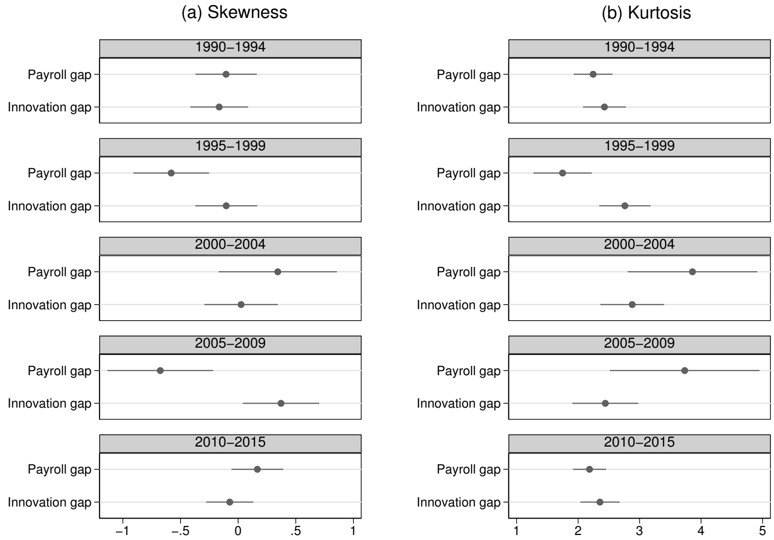




Note: Wage bill (i.e., annual payroll) data comes from the Quarterly Census of Employment & Wages (QCEW). Nominal values were deflated using the BLS consumer price index CPI-U (2012=100) and rescaled into logarithms. Patents data comes from patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017). Percentiles are constructed as the weighted sum of the share of aggregate value (AV) of U.S public firms in 2001 Crouzet and Eberly, [2018], Hall [2018]. High-tech industries (software and telecommunications) are collapsed at three-digit North American Industry Classification Structure (NAICS) and KLEMS level: 334, 511, 512, 515, 517, 518, 519 and 541 respectively. Appendix A.2 contains a brief description of each industry. For a clear visual inspection, patents are rescaled per 100,000 population and transformed into logarithms. The analysis excludes States with missing data (West Virginia, Wyoming), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Source: author own calculations.

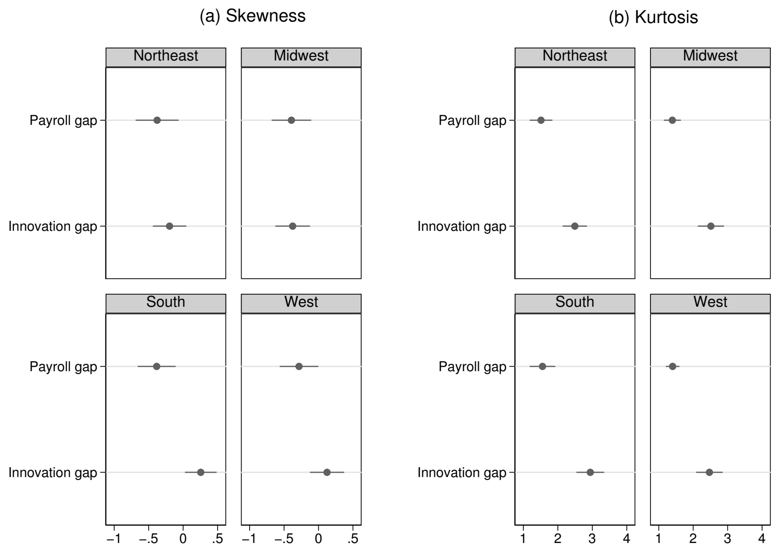
Measures of shape for selected variables

FIGURE A.3.4: Wage gap and innovation gap by quinquennial



Note: Payroll gap is the difference between the 90^{th} and 10^{th} percentile of real wages; innovation gap is the difference between 90^{th} and 10^{th} patents and scientific citations. Source: Author own calculations based on County Business Paterns (CBP), patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017).

FIGURE A.3.5: Wage gap and innovation gap by regions



Note: Payroll gap is the difference between the 90^{th} and 10^{th} percentile of real wages; innovation gap is the difference between 90^{th} and 10^{th} patents and scientific citations. Source: Author own calculations based on County Business Paterns (CBP), patents view, a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020) and Arora et al. (2017).

A.4 Additional Results

Employment Models: Non-Spatial OLS Results

TABLE A.4.1: Infrastructure, employment and incentives: OLS estimates

dv: job creation rate	All			Top value-added			Bottom value-added		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
(log of) Highway spending	−0.235	−0.262	−0.708*	−0.273	−0.297	−0.731*	−2.558***	−2.549***	−1.442*
	[0.231]	[0.220]	[0.374]	[0.240]	[0.231]	[0.409]	[0.600]	[0.596]	[0.749]
(log of) Private non-residential spending	0.681**	0.687**	0.873*	0.874**	0.895**	0.957*	0.566	0.476	0.481
	[0.282]	[0.295]	[0.484]	[0.265]	[0.277]	[0.497]	[0.530]	[0.518]	[0.614]
(log of) Policy diffusion score	0.661**	0.667**	0.590*	0.750**	0.751**	0.603	0.049	0.079	0.853
	[0.305]	[0.303]	[0.326]	[0.313]	[0.311]	[0.364]	[0.606]	[0.614]	[0.800]
R&D incentive (0-3 years)			43.120**			36.663*			69.228**
			[16.628]			[17.687]			[24.699]
R&D user cost (0-3 years)			−5.507			−6.000			−14.125**
			[5.378]			[5.609]			[6.666]
R&D incentive × R&D user cost			−12.621**			−10.749*			−20.168**
			[4.837]			[5.153]			[7.166]
GDP growth rate (net infrastructure)	0.157***	0.156***	0.119***	0.161***	0.159***	0.119***	0.113	0.119	0.061
	[0.026]	[0.027]	[0.023]	[0.028]	[0.029]	[0.026]	[0.082]	[0.083]	[0.057]
R-squared (within)	0.096	0.096	0.346	0.095	0.095	0.316	0.043	0.044	0.213
Wooldridge AR-1 test (p-value)	(0.001)	(0.001)	(0.016)	(0.005)	(0.004)	(0.047)	(0.062)	(0.053)	(0.048)
Number of states	48	48	48	48	48	48	48	48	46
Number of observations	1055	1053	1053	1038	1036	1036	929	928	902
Geography controls	N	Y	Y	N	Y	Y	N	Y	Y
Socioeconomic controls	N	N	Y	N	N	Y	N	N	Y
Institutional controls	N	N	Y	N	N	Y	N	N	Y
Supply controls	N	N	Y	N	N	Y	N	N	Y

Notes:
a. All models include Census divisions fixed effects. Additionally, since annual public expenditures vary in sample size, I include a dummy break to account for time fixed effects without compromising the number of covariates. Indeed, its inclusion (not reported) was highly significant in almost all specifications, meaning that this effect cannot be disregarded. Geography controls include average temperatures in winter (January) and summer (July) while socioeconomic ones regard the high school and college graduation rates from total state population. Last but not least, we account for the institutional quality by employing all the disaggregated scores (i.e., subcategories) of the EFNA named: Government spending, Taxation and Labor Market Freedom. For more details see Appendix A.1. Finally, we control for supply shocks with a dummy variable equal to one when the economy had downturns periods (e.g. 1990-91; 2001 and 2008-2010) and zero in contrary case.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and rescaled into logarithms.
c. Real private non-residential spending comes from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Source: Quarterly Census of Employment & Wages (QCEW).
e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value share— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.
f. For the high-tech incentive dummy we consider those states in which R&D tax-credits were positive. Data comes from the Panel Database of Incentives and Taxes (PDIT) (Bartik, 2017). While R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90^{th} percentile) which is about half of the IRS income data (i.e., 0.2588).
g. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.2 lists the full set of policies.
h. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were excluded from the analysis. Also we account for outliers (Delaware, Maine). Robust standard errors clustered at State level in brackets (Imbens and Kolesar (2016) small sample adjustment). *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table A.4.2: Infrastructure, employment, incentives and innovation: OLS estimates

dv: job creation rate	All			Top value-added			Bottom value-added		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
(log of) Highway spending	−0.641**	−0.650**	−0.903*	−0.635**	−0.636**	−0.899*	−2.244**	−2.257**	−1.516*
	[0.287]	[0.286]	[0.449]	[0.265]	[0.264]	[0.486]	[0.650]	[0.657]	[0.860]
(log of) Private non-residential spending	0.970**	0.926**	1.153*	1.135**	1.108**	1.214*	0.202	0.129	0.544
	[0.339]	[0.341]	[0.566]	[0.343]	[0.345]	[0.608]	[0.546]	[0.543]	[0.543]
(log of) Patents (10^{th} percentile)	0.122	0.025	0.106	−0.004	−0.008	0.099	0.095	0.083	0.187
	[0.075]	[0.076]	[0.090]	[0.069]	[0.071]	[0.097]	[0.205]	[0.210]	[0.108]
(log of) Patents (25^{th} percentile)	−0.521**	−0.499**	−0.404	−0.360	−0.350	−0.370	−0.813	−0.790	−0.759*
	[0.201]	[0.207]	[0.275]	[0.207]	[0.212]	[0.281]	[0.538]	[0.547]	[0.407]
(log of) Patents (75^{th} percentile)	0.468**	0.462**	0.452**	0.348**	0.342**	0.370*	0.768	0.756	1.177**
	[0.156]	[0.162]	[0.187]	[0.145]	[0.151]	[0.186]	[0.513]	[0.508]	[0.409]
(log of) Patents (90^{th} percentile)	−0.203**	−0.197**	−0.107	−0.154*	−0.150*	−0.058	−0.329*	−0.322*	−0.469**
	[0.081]	[0.082]	[0.137]	[0.085]	[0.086]	[0.138]	[0.188]	[0.187]	[0.215]
R&D incentive (0-3 years)			39.587**			34.507*			68.518**
			[17.854]			[19.399]			[23.259]
R&D user cost (0-3 years)			−9.452			−8.734			−19.888**
			[6.387]			[6.731]			[6.334]
R&D incentive × R&D user cost			−11.582**			−10.114*			−19.933**
			[5.175]			[5.631]			[6.764]
GDP growth rate (net infrastructure)	0.175***	0.177***	0.112***	0.173***	0.174***	0.113***	0.093	0.097	0.054
	[0.033]	[0.034]	[0.025]	[0.036]	[0.036]	[0.027]	[0.088]	[0.089]	[0.063]
R-squared (within)	0.090	0.091	0.367	0.081	0.081	0.344	0.036	0.037	0.252
Wooldridge AR-1 test (p-value)	(0.005)	(0.004)	(0.071)	(0.015)	(0.013)	(0.127)	(0.067)	(0.058)	(0.113)
Number of states	45	45	45	45	45	45	45	45	44
Number of observations	849	848	848	841	840	840	784	783	770
Geography controls	N	Y	Y	N	Y	Y	N	Y	Y
Socioeconomic controls	N	N	Y	N	N	Y	N	N	Y
Institutional controls	N	N	Y	N	N	Y	N	N	Y
Supply controls	N	N	Y	N	N	Y	N	N	Y

Notes:
a. All models include Census divisions fixed effects. Additionally, since annual public expenditures vary in sample size, I include a dummy break to account for time fixed effects without compromising the number of covariates. Indeed, its inclusion (not reported) was highly significant in almost all specifications, meaning that this effect cannot be disregarded. Geography controls include average temperatures in winter (January) and summer (July) while socioeconomic ones regard the high school and college graduation rates from total state population. Last but not least, we account for the institutional quality by employing all the disaggregated scores (i.e., subcategories) of the EFNA named: Government spending, Taxation and Labor Market Freedom. For more details see Appendix A.1. Finally, we control for supply shocks with a dummy variable equal to one when the economy had downturns periods (e.g. 1990-91; 2001 and 2008-2010) and zero in contrary case.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and rescaled into logarithms.
c. Real private non-residential spending was obtained from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and rescaled by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Job-creation rates (private employment) were calculated as the difference of the ratio in employment levels in period t with respect to t-1 times 100. Source: Quarterly Census of Employment & Wages (QCEW).
e. We concentrate on the most innovative industries (i.e., the distribution —in terms of aggregate value share— of patents and scientific citations of all software and telecommunications industries). Thus, our top 4 group, based on the three-digit North American Industry Classification Structure (NAICS) includes the following sectors: 334, 511, 517 and 541. Conversely, the bottom 4 encompass 512, 515, 518 and 519. Appendix A.1 contains a brief description of each industry.
f. For the high-tech incentive dummy we consider those states in which R&D tax-credits were positive. Data comes from the Panel Database of Incentives and Taxes (PDIT) (Bartik, 2017). While R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90^{th} percentile) which is about half of the IRS income data (i.e., 0.2588).
g. The analysis excludes States with missing data (West Virginia, Wyoming), outliers (Delaware, Maine), the District of Columbia (DC) and States not part of the contiguous United States (Alaska and Hawaii). Robust standard errors clustered at State level in brackets (Imbens and Kolesar (2016) small sample adjustment). *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Spatial Lag Model (SLX)

In order to construct the bilateral weighted distance we need to define an spatial lag set up as in time series models (LeSage and Pace, 2009). Naturally, dependence among units is likely to occurs (e.g. some bordering counties, municipalities and states). Therefore, for the sake of simplicity we first define a two dimensional matrix as later we will use a third order matrix. Then, following Kondo (2016) the matrix takes the following form:

$$W = \begin{pmatrix} 0 & w_{1,2} & w_{1,3} & \dots & w_{1,n} \\ w_{2,1} & 0 & w_{2,3} & \dots & w_{2,n} \\ w_{3,1} & w_{3,2} & 0 & \dots & w_{3,n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{1,n} & w_{2,n} & w_{3,n} & \dots & 0 \end{pmatrix}$$

where the diagonal matrix elements are zero and the sum of each row takes the value of 1 (i.e. row standardization). Now, let x be the vector of a variable (e.g. technological patents). Then, the spatially lagged matrix W can be expressed as:

$$\mathbf{W} \cdot \mathbf{x} = \begin{pmatrix} \sum_{j=1}^{n} w_{1j}x_j \\ \sum_{j=1}^{n} w_{2j}x_j \\ \sum_{j=1}^{n} w_{3j}x_j \\ \vdots \\ \sum_{j=1}^{n} w_{nj}x_j \end{pmatrix} \cdot \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{pmatrix}$$

It is worth stressing that each element of the spatially lagged variable Wx depicts the weighted average of neighbouring regions. Thus, the diagonal elements of the matrix must be zero to exclude the own regional values in the spatially lagged variable. In our case, we employ a third order spatially lagged matrix weighted by the net GDP growth rate excluding infrastructure investments (both public and private). Formally, our matrix is as follows: $W^3x = W \times (Wx)^2$ and for the row-standardized matrix we use the aforementioned variable v with a power functional type form:

$$w_{ij} = \begin{cases} \frac{v_j d_{ij}^{-\delta}}{\sum_{j=1}^{n} v_j d_{ij}^{-\delta}}, & if\ d_{ij} < d,\ i \neq j,\ \delta > 0 \\ 0, & otherwise \end{cases}$$

where v_j is a weight variable of region j, δ is a distance decay parameter and d is a threshold distance measure (miles or kilometres) which can be arbitrary. For the empirical analysis we employ a power 6 to avoid persistence with the dependent variable (job creation rates in different high-tech industries). Simple pairwise correlations between the inverse spatially weighted variable and the dependent variable confirms a decreasing and insignificant correlation for that particular power.

Wage Models

Table A.4.3: Normality tests for panel data models: without controls

	Error (innovation term)			State (specific term)		
Panel A: Top value-added	Skewness	Kurtosis	Joint (p-value)	Skewness	Kurtosis	Joint (p-value)
Coefficient	-1.016^{***}	2.387^{***}	140.850^{***}	-1.264^{**}	2.680^{**}	11.080^{**}
Std.Error	[0.111]	[0.316]	(0.000)	[0.521]	[1.175]	(0.004)
Panel B: Bottom value-added	Skewness	Kurtosis	Joint (p-value)	Skewness	Kurtosis	Joint (p-value)
Coefficient	-0.262^{**}	-0.135	6.470^{**}	-1.362^{***}	1.899^{**}	20.140^{***}
Std.Error	[0.113]	[0.130]	(0.039)	[0.355]	[0.818]	(0.000)

Notes:
a. We perform the analysis for our two industries including the GDP growth rate (excluding both measures of infrastructure) and dummies by the four U.S aggregated regions (Northeast, Midwest, South and West) and decades.
b. Bootstrap standard errors (800 replications) in brackets while p-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table A.4.4: Quantile wage decomposition: without controls

Panel A: Top value-added	IV fixed effects	Nonadditive fixed effects				
dv: (log of) Real payroll	(Mean)	q(10)	q(25)	q(50)	q(75)	q(90)
(log of) Highway spending	-0.135	-0.163^{***}	-0.097^{***}	-0.087^{***}	-0.053^{***}	-0.161^{***}
	[0.086]	[0.006]	[0.003]	[0.005]	[0.000]	[0.001]
(log of) Private non-residential spending	-0.102^{*}	-0.009	0.020	0.023^{***}	0.020^{***}	0.014^{***}
	[0.058]	[0.012]	[0.014]	[0.005]	[0.001]	[0.002]
(log of) Patents per-capita	0.075^{*}	0.119^{***}	0.085^{***}	0.070^{***}	0.084^{***}	0.075^{***}
	[0.021]	[0.003]	[0.002]	[0.002]	[0.000]	0.000^{***}
(log of) Policy diffusion score	0.002	0.021^{***}	0.023^{***}	-0.002	0.072^{***}	0.071^{***}
	[0.046]	[0.006]	[0.003]	[0.016]	[0.001]	[0.001]
Observations	810	848	848	847	848	848
Number of states	46	46	46	46	46	46
Panel B: Bottom value-added	IV fixed effects	Nonadditive fixed effects				
dv: (log of) Real payroll	(Mean)	q(10)	q(25)	q(50)	q(75)	q(90)
(log of) Highway spending	-0.351^{**}	-0.316^{***}	-0.327^{***}	-0.237^{***}	-0.174^{***}	-0.144^{***}
	[0.107]	[0.005]	[0.009]	[0.004]	[0.002]	[0.007]
(log of) Private non-residential spending	0.096	-0.277^{***}	-0.081^{***}	0.015^{***}	0.274^{***}	0.291^{***}
	[0.133]	[0.005]	[0.006]	[0.004]	[0.005]	[0.013]
(log of) Patents per-capita	0.103^{**}	0.119^{***}	0.098^{***}	0.122^{***}	0.124^{***}	0.096^{***}
	[0.028]	[0.001]	[0.003]	[0.001]	[0.000]	[0.001]
(log of) Policy diffusion score	-0.195^{**}	-0.361^{***}	-0.176^{***}	-0.331^{***}	-0.113^{***}	0.047^{***}
	[0.073]	[0.004]	[0.008]	[0.013]	[0.005]	[0.005]
Observations	751	789	789	788	789	789
Number of states	46	46	46	46	46	46

Notes:
a. Conditional mean estimates correspond to the two-way (Census divisions and decades) fixed effects model. The Hansen test (not reported) which tests the validity of the instruments is not rejected in any of the two groups.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and normalized by state population to control for business cycle effects.
c. Real private non-residential spending was obtained from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and normalized by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Patents are the weighted sum of aggregate value share (AV) of U.S public firms in 2001. In lieu with economic literature, patents are rescaled per 100,000 population. Data comes from Arora et al. (2017), patents view and a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020).
e. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.3 lists the full set of policies.
f. The quantile panel model with nonadditive fixed effects is estimated including the GDP growth rate (excluding both measures of infrastructure) and dummies by U.S Census division and decades. Robust standard errors in brackets are computed by bootstrap method with 800 replications using the Metropolis-within-Gibbs sampler. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table A.4.5: Normality tests for panel data models: Additional controls

	Error (innovation term)			State (specific term)		
Panel A: Top value-added	Skewness	Kurtosis	Joint (p-value)	Skewness	Kurtosis	Joint (p-value)
Coefficient	−0.925***	2.347***	140.190***	−2.230***	6.274***	26.760***
Std.error	[0.114]	[0.272]	(0.000)	[0.503]	[2.355]	(0.000)
Panel B: Bottom value-added	Skewness	Kurtosis	Joint (p-value)	Skewness	Kurtosis	Joint (p-value)
Coefficient	−0.411**	0.335*	14.800**	−1.779***	2.494	24.880***
Std.error	[0.122]	[0.180]	(0.001)	[0.377]	[1.533]	(0.000)

Notes:
a. We perform the analysis for our two industries using the same controls from employment models excluding the R&D interaction variable along with dummies by the four U.S aggregated regions (Northeast, Midwest, South and West) and decades. In addition we add a dummy variable equal to 1 if state minimum wages are higher than federal ones. Data comes from Vaghul and Zipperer (2016).
b. Bootstrap standard errors (500 replications) in brackets while p-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

Table A.4.6: Quantile wage decomposition: Additional controls

Panel A: Top value-added	IV fixed effects	Nonadditive fixed effects				
dv: (log of) Real payroll	(Mean)	q(10)	q(20)	q(50)	q(75)	q(95)
(log of) Highway spending	0.026	−0.096***	−0.078***	−0.002	0.004**	0.058***
	[0.071]	[0.003]	[0.003]	[0.003]	[0.002]	[0.008]
(log of) Private non-residential spending	0.030	0.048***	0.084***	0.119***	0.118***	−0.003
	[0.057]	[0.007]	[0.003]	[0.004]	[0.002]	[0.023]
(log of) Patents per-capita	0.016	0.061***	0.033***	0.021***	0.007***	0.014***
	[0.013]	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]
(log of) Policy diffusion score	−0.070	0.002	0.017***	−0.044***	−0.054***	−0.021***
	[0.048]	[0.003]	[0.002]	[0.004]	[0.003]	[0.005]
R&D incentive (0-3 years)	−0.114**	−0.076***	−0.057***	−0.066***	−0.077***	−0.142***
	[0.042]	[0.002]	[0.001]	[0.002]	[0.002]	[0.007]
R&D user cost (0-3 years)	−1.866**	0.219***	0.142***	−0.091	0.596***	1.348***
	[0.503]	[0.055]	[0.026]	[0.085]	[0.022]	[0.052]
Δ State minimum wage	0.136**	0.117***	0.152***	0.161***	0.105***	0.083***
	[0.049]	[0.004]	[0.002]	[0.005]	[0.002]	[0.008]
Observations	810	847	847	847	847	847
Number of states	46	46	46	46	46	46
Panel B: Bottom value-added	IV fixed effects	Nonadditive fixed effects				
dv: (log of) Real payroll	(Mean)	q(10)	q(20)	q(50)	q(75)	q(95)
(log of) Highway spending	−0.104	0.035***	−0.067***	−0.145***	−0.151***	0.225***
	[0.087]	[0.003]	[0.005]	[0.006]	[0.015]	[0.037]
(log of) Private non-residential spending	0.012	−0.304***	−0.114***	0.034***	0.046***	0.104***
	[0.112]	[0.003]	[0.009]	[0.007]	[0.013]	[0.043]
(log of) Patents per-capita	0.013	0.041***	0.024***	0.040***	0.048***	−0.038***
	[0.028]	[0.001]	[0.002]	[0.004]	[0.002]	[0.009]
(log of) Policy diffusion score	−0.178**	−0.169***	−0.239***	−0.139***	−0.067***	−0.398***
	[0.070]	[0.004]	[0.012]	[0.005]	[0.007]	[0.048]
R&D incentive (0-3 years)	−0.121	−0.170***	−0.193***	−0.112***	0.020**	−0.150***
	[0.084]	[0.007]	[0.004]	[0.002]	[0.009]	[0.051]
R&D user cost (0-3 years)	2.938**	1.788***	2.039***	3.988***	5.293***	2.385
	[0.819]	[0.015]	[0.101]	[0.218]	[0.112]	[1.513]
Δ State minimum wage	0.199**	0.169***	0.286***	0.104***	0.002	−0.521***
	[0.078]	[0.007]	[0.010]	[0.008]	[0.019]	[0.032]
Observations	751	788	788	788	788	788
Number of states	46	46	46	46	46	46

Notes:
a. Conditional mean estimates correspond to the two-way (Census divisions and decades) fixed effects model. The Hansen test (not reported) which tests the validity of the instruments is not rejected in any of the two groups.
b. Real capital outlays of highway spending includes: maintenance, operation, purchases of equipment, toll highways, bridges, tunnels, ferries, street lighting, snow and ice removal. The real measure was computed using the State price index provided by the Bureau of Economic Analysis (BEA) (table 3.9.4) and normalized by state population to control for business cycle effects.
c. Real private non-residential spending comes from U.S Census and deflated by the BLS consumer price index CPI-U (2012=100) and normalized by state population to control for business cycle effects. Data starts from 1993 onwards.
d. Patents are the weighted sum of aggregate value share (AV) of U.S public firms in 2001. In lieu with economic literature, patents are rescaled per 100,000 population. Data comes from Arora et al. (2017), patents view and a crosswalk of U.S public firms (COMPUSTAT) Autor et al. (2020).
e. The policy diffusion score includes 204 policies for the following sectors: education, energy, environment, domestic commerce, housing, labor and macroeconomics. Appendix A.3 lists the full set of policies.
f. R&D user cost was constructed following Wilson (2009). For the expenditure share (s) we use COMPUSTAT data (instead of IRS) which is on average 0.1243 between the years 1965 and 2015 rather than 0.5. Particularly, we concentrate on the upper bound (90th percentile) which is about half of the IRS income data (i.e., 0.2588).
g. Dummy variable equal to one for years in which state minimum wages were higher than federal ones. Data comes from Vaghul and Zipperer (2016).
h. The District of Columbia (DC) as well as Alaska and Hawaii (not part of the contiguous United States) were automatically excluded from the analysis. Robust standard errors in brackets are computed by bootstrap method with 500 replications using the Metropolis-within-Gibbs sampler. *** p<0.01, ** p<0.05, * p<0.1. Source: author own calculations.

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Appendix: Chapter III

B.1 Real Business Cycle Model (RBC)

In order to compare our findings from the heterogeneous-agent economy (incomplete-markets) with those from its representative-agent equivalent, we develop a simple Real Business Cycle (RBC) (discrete time) model with an endogenous labor supply, public capital investments, government consumption and lump sum transfers.

Furthermore, we assume that the stock of infrastructure is well-maintained; thus, preventative expenditures are ruled out. In this simplified RBC model, utility does not depend on the aggregate stock of infrastructure in the economy. Therefore, the functional form of utility as well as its parameters are the same as in the heterogeneous model framework: (equation 3.1), i.e., additively-separable with the standard constant relative risk aversion (CRRA) over consumption and convex disutility over hours worked.

In this set up, markets are complete as agents have certainty (there is a complete set of Arrow-Debreu contingent claims) while in the incomplete markets setting there is a distribution of agents with different (total) resources which reflect different histories of labor endowments given by the presence of uninsurable (or partly insurable) idiosyncratic shocks. Accordingly, under incomplete markets, workers with lower productivity and lower resources (e.g. family informal workers) are more likely to face uncertainty whilst those with higher resources and productivity levels (e.g. private and self-employed workers) will accumulate assets beyond the constrained restriction (b). In addition, there is a government fiscal rule (i.e. balanced budget between revenues and expenditures) as a part of the steady-state. Thus, household's optimal decisions will not change as the government supplies infrastructure and makes lump sum transfers (i.e. taxation effects are neutral).

Households

The economy is populated by a large number of agents (infinitely-lived households), for convenience its measure is normalized to the unity. The utility function is additively-separable with the standard constant relative risk aversion (CRRA) over consumption and convex disutility over hours worked. Formally, household's maximise the the following problem:

$$\max_{\{c_t,h_t,k_{t+1}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t) - v(h_t) \tag{B.1.1}$$

subject to

$$c_t + k_{t+1} = w_t z_t h_t + T + [1 + (r_t - \delta)]\, k_t \tag{B.1.2}$$

where $c_t \geq 0$ denotes the consumption, $h_t \geq 0$ the hours worked, $z_t > 0$ $z_{t+1} \prod (z_{t+1}|z)$ is the stochastic labor productivity shock along its probability distribution function. Additionally, $k_t > 0$ denotes the aggregate physical capital (including public infrastructure), δ is the depreciation rate, β denotes the subjective discount factor, both w_t and r_t are the market factor prices: real wages and real interest rate and T government lump sum transfers. Notice that the introduction of T into the budget constraint does not alter Household's optimal decisions. Accordingly, optimal intratemporal and intertemporal decision rules of the representative-household's are the following:

$$v'(h_t) = u'(c_t) z_t w_t \tag{B.1.3}$$

$$u'(c_t) = \beta \mathbb{E}_t \left[u'(c_t')(1 + r_t) \right] \tag{B.1.4}$$

where the prime notation refers to next period and the expectations operator is defined over the future consumption paths. As usual, the first decision (the intratemporal condition), refers to the consumption-leisure efficiency condition in terms of the stochastic shock process. In plain words, in the margin the optimal number of hours worked equals the (future) consumption given by the possible realizations of the labor productivity shock (although in this case there is certainty as b is not binding). Conversely, the intertemporal margin states that the subjective discount factor is the bridge between present and future consumption. Of course, during transitions higher (lower) β imply lower (higher) levels of steady state consumption as household's are more (less) impatient. Nonetheless, the present paper focuses only on the steady-state values (long-run) for both incomplete and complete markets; hence, short-run effects that occur during the transition path are shut-down.[1]

[1] Is it is worth noticing that short-run dynamics may have sizeable effects over household's consumption-labor decisions and thereby wealth. For more details on the transitional dynamics see Chatterjee and Turnovsky (2012) and Turnovsky (2004).

Firms

There is a competitive representative neoclassical firm that faces constant returns to scale in the production technology and maximizes profits taking prices as given, i.e., the wage rate and the real interest rate. Accordingly, the firm solves the following (static) problem:

$$\max_{\{K,L\}} (1-\tau) K_I^{\Phi} K^{\alpha} L^{1-\alpha} - wL - (r+\delta) K \tag{B.1.5}$$

where τ is the output tax rate, $\Phi < 1$ is the elasticity of output with respect to the stock of infrastructure K_I, $0 < \alpha < 1$, K and L denote aggregate physical capital and effective labor demand by the firm respectively, w is the wage rate, r is the rental rate on capital both market clearing and δ is the (endogenous) depreciation rate of aggregate physical capital. Optimal decision yields the standard results: the real interest rate and the wage rate are both determined competitively and equal to their respective factor's marginal products.

$$\alpha K^{\alpha-1} L^{1-\alpha} - r + \delta = 0 \longleftrightarrow r = F_K(K,L) - \delta \tag{B.1.6}$$

and

$$1 - \alpha K^{\alpha} L^{-\alpha} - w = 0 \longleftrightarrow w = F_L(K,L) \tag{B.1.7}$$

Government

In this economy, the government invests in public infrastructure K_I (e.g., roads/highways and/or water sanitization services), consumption goods G and makes lump sum transfer T to household's. Naturally, in order to provide such services the government levies a tax τ on aggregate output (Y). For simplicity, we assume that the government allocates proportionally each service so that the budget is balanced. In other words, $\tau_{K_I} + \tau_G + \tau_T = \tau$. Moreover, as we are only interested on the consumption-working hours (endogenous) choice of household's in one year, again we assume that private capital depreciation rate is less responsive than public capital one. Accordingly, the resource constraint is simply Total Spending (TS) equal Total Revenues (TR):

$$G + T + \delta K_I = \tau Y \tag{B.1.8}$$

where G denotes government consumption, T are lump sum transfers, δ the depreciation rate of public infrastructure (as in the Aiyagari regime it depends on the use of e-Procurement services) and τ is a constant tax rate on output Y.

Steady-state

As Campbell (1994) explains, the behavior of dynamic stochastic general equilibrium (DSGE) models can be best understood by working out approximated solutions. Indeed, it is a common practise to make log-linear approximations (also known as Campbell equations) derived from dynamic optimization condition of economic agents around a deterministic steady state. For our RBC model, the deterministic steady-state can be defined as that the stochastic labor process z_t, which is equal its long-run value $\overline{z}$ and all the choice and state variables converging to their long-run values: $c_t = c_{t+1} = \ldots \overline{c}$, $h_t = h_{t+1} = \ldots \overline{h}$, $k_t = k_{t+1} = \ldots \overline{k}$ while given prices, optimality conditions by the representative household (B.1.3), (B.1.4) and by the representative firm (B.1.6) and (B.1.7) hold. In addition, markets clear via factor prices $\overline{w}$ and $\overline{r}$ so that capital and labor demand by the firm equals capital and labor supply by the household and government budget is balanced: i.e., consumption τ_G, transfers τ_T and infrastructure τ_{K_I} are equal to available resources: τY. Accordingly, the steady-state of this economy can be characterized by the following equations:

$$v'\left(\overline{h}\right) = u'\left(\overline{c}\right)\overline{zw} \tag{B.1.9}$$

$$u'\left(\overline{c}\right) = \beta\left[u'\overline{c}\left(1+\overline{r}\right)\right] \tag{B.1.10}$$

$$\frac{1}{\beta} = 1+\overline{r} \tag{B.1.11}$$

$$\overline{r} = F_K\left(\overline{K}, \overline{L}\right) - \delta \tag{B.1.12}$$

$$\overline{w} = F_L\left(\overline{K}, \overline{L}\right) \tag{B.1.13}$$

$$TS = \overline{G} + \overline{T} + \delta\overline{K_I} \tag{B.1.14}$$

$$TR = \tau\overline{Y} \tag{B.1.15}$$

$$TS = TR \tag{B.1.16}$$

To solve numerically the deterministic steady-state of the representative-agent economy, we rely on the same parameter values as in the in the heterogeneous-agent model (Table 3.1).

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