Does the R&D Public Procurement Matter for High-Tech Exports? Evidence from the USA *

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Abstract

Recently, demand-side innovation policies have succeeded in stimulating economic growth on developed countries. Especially, public procurement has become a major industrial policy for innovation. The paper investigates the impact of R&D public procurement on high-tech exports in the USA. Using data on federal procurement in the USA and performing panel fixed-effects estimations, I provide a comprehensive econometric assessment of the link between R&D public procurement and high-tech exports. Due to reverse causality bias, I perform the instrumental variable approach to examine the causal effect of the R&D public procurement on high-tech exports. The instrumental-variable estimations use the number of senators in the senate appropriation committee as an instrument for R&D public procurement. The main basic OLS result suggests that an increase by 1% in R&D public procurement implies an increase in high-tech exports by 4.9%. The IV results suggest the causal interpretation of the OLS results.

Keywords: Public procurement, High-tech exports, Innovation, The USA

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1 Introduction

Public procurement has become a multi-objective policy which can induce innovation, international competitiveness, job creation, reduce market failure,and foster the economic growth. Purchases of high-tech goods and services represent a big proportion of public budgets in developed countries. Specifically, the U.S. government is the largest public purchaser in the world. The U.S. government has spent a vast amount of its budget into public procurement. It has spent half a trillion dollars annually on purchases of goods and services. Public procurement represents around of are about 35 percent of gross domestic product.The department of defense, energy, general services administration, and NASA perform the biggest share of procurement (Vonortas, Bhatia, & Mayer, 2015).

The objective of the paper is to estimate the effect of R&D public procurement on high-tech exports in the USA. In the past two decades, many countries (i.e., United States, and European countries) have suffered from slower rates of economic growth. Despite adopting and refining supply-side innovation policies, these policies fails in achieving the diffusion and adoption of innovative products or services within the market. Recently, a growing interest in demand-side innovation policies has increased since they have achieved a great success in stimulating the technological development and the diffusion of innovations. Specifically, public procurement as a demand-side innovation policy has created a positive shock which induces firms to be more innovative and productive in high-tech industries. Hence, it raises the ability to perform high-tech exports (Vonortas et al., 2015).

Generally, public procurement refers to the purchase of the public or government institutions. Public procurement can be categorized in two types; one is innovation-oriented procurement, and the other is non-innovation-oriented procurement. The public demand can reduce market uncertainty and spur firms to spend more on private R&D and to be more innovative. Guaranteeing demand can spur firms to adopt technology and to produce more sophisticated products. The public sector can be a lead user which creates an environment of trust and encourage the local users to purchase new invented products. Accordingly, the public demand can guarantee the profits for private innovation. Technological uncertainty is another type of uncertainty which faces firms. Moreover, the public demand can test the ground of the innovation results. It can update suppliers with modifications and feedbacks. It can reduce market failure and information asymmetries by enabling interactions between suppliers and customers. the public needs can be demanding and highly-sophisticated. Accordingly, the public demand can spur firms to follow high international standards and to be more competitive in foreign markets (Uyarra, Edler, Garcia-Estevez, Georghiou, & Yeow, 2014).

Previous empirical studies pay less attention to examine the correlation between public procurement and high-tech exports. Instead, they have discussed the effect of total public and private expenditure on exports. Previous studies have different results and conclusions about the effect of R&D expenditure on high-tech exports. Moreover, Some evidence suggests a positive correlation however other evidence documents no impact of R&D expenditure on high-tech exports. There is much macro evidence to confirm the positive correlation between R&D expenditure and exporting performance (Greenhalgh (1990), Narula and Wakelin (1998), Montobbio and Rampa (2005), Dipietro and Anoruo (2006)), Harris and Li (2008), Sandu and Ciocanel (2014)). At the micro level, the empirical evidence is inconclusive. While some evidence at micro level confirms a positive and significant impact of R&D expenditure on export performance (Basile (2001),Smith et al.(2002), and Barber and Alegre (2007)), other evidence fails to find an effect of R&D expenditure on exporting performance (Wakelin (1998), Lefebvre et. al. (1998), Sterlacchini (1999), and Becchetti and Rossi (2000)).

Reverse causality bias arises since high-tech exports of some industries might attract more public R&D expenditure. Accordingly, most analyses are unable to identify the causal relationship between public expenditure and high-tech exports. Empirical evidence uses different methods such as GMM, panel fixed effect, and pooled least squares to identify the causal effect of R&D public expenditure on high-tech exports (Braunerhjelm and Thulin (2008), Sandu and Ciocanel (2014)). However, these methods are inconclusive in providing a critical solution to the endogeneity problem. For example, Sandu and Ciocanel (2014) use panel fixed effect estimations to investigate the impact of public and private research & development expenditure on high-tech export. They use panel data of all European countries from 2006 to 2010. Results show that the private R&D expenditure is stronger than public R&D expenditure in increasing high-tech exports.

I contribute to recent studies documenting the relationship between the public R&D expenditure and high-tech exports in a number of ways. First, it is the first paper which provides an empirical evidence of the relationship between R&D public procurement and high-tech exports. Second, I use a new instrumental variable to examine the causal effect of the R&D public procurement on high-tech exports. Third, I contribute to previous studies by providing a new state-level evidence in the USA. The U.S. public sector is the largest procurer in the world, allocating a large proportion of its budget on purchases. It is important to check whether the relationship would survive among different types of public expenditures.

I get data on high-tech exports as a dependent variable from the United States Census Bureau. I aggregate the data at the state level using the NAICS classification and the high-tech industry definition of the Bureau of Labor Statistics (Hecker, 2005). To measure R&D public procurement, I use administrative data on public procurement contracts in the United States constructed by Slavtchev and Wiederhold unique dataset. It uses the federal procurement data system-next generation (FPDS-NG), provided by the general services administration (GSA).

To account for other control variables, I use data on FDI, federal aid to state, population, GDP growth rate of high-tech industries, and the real GDP of state from the U.S. Bureau of Economic Analysis (BEA). Furthermore, I use data on university expenditure on R &D, graduates in science and engineering, federal expenditure on R &D, and private

R &D expenditure. This data is obtained from the Survey of Industrial R&D (SIRD), administered by the National Science Foundation (NSF). To measure utility patent counts, I use data from the U.S. Patent and Trademark Office (USPTO). I get data on the number of senators in senate appropriation committee, which is the instrumental variable, from the Slavtchev and Wiederhold unique dataset.

First, I start with the OLS approach to estimate the impact of R&D public procurement on high-tech exports. However, the OLS estimates are biased because there might be further unobserved factors that are associated with both R& D public procurement and high-tech exports. For example, the number of federal procurement contracts might depend on state characteristics such as policy changes and regulations which are correlated with exports. Furthermore, the reverse causality problem arises since the ability of firms to perform high-tech exporting may attract more R&D public procurement contracts. The paper follows four strategies to reduce the OLS bias. The first strategy is to mitigate the omitted variable bias by accounting for many covariates which might drive results. The second strategy is to use the instrumental variable approach to solve the problem of endogeneity. The third strategy is to use the state fixed effect to account for unobservable time-invariant factors. The fourth strategy is to use the time fixed effect to account for unobservable time-varying factors which might be associated with public procurement and high-tech exports.

The first strategy is to control for covariates which might lead to spurious correlation. For example, private R&D expenditure and FDI might be potential confounders since they might be associated with public procurement and high-tech exports. Also, I control for changes in a state's industry structure by adding the GDP growth rate of high-tech industries. For instance, the growth of high-tech industries in a state may be correlated with a larger amount of procurement and more exports. The U.S. government has the largest university and federal expenditure in the world. Such different expenditures may lead to a spurious correlation. I then control for different other types of government expenditures. The second strategy is to use the instrumental variable approach to address the endogeneity concern. I use the exogenous variation of public procurement from the senate appropriation committee to identify the causal effect of R&D public procurement on high-tech exports. Regarding the relevance condition, the state, which has representation in the committee, gains a big advantage of getting more appropriations and public purchases contracts rather than other states. The full appropriations committee contains twelve subcommittees. The main role of them is to authorize the appropriations according to the decisions of the Congress toward the budget. All first stage tables show that there is a positive and significant correlation between the number of senators in the senate appropriation committee and the R&D public procurement. It implies that there is a relevant instrument (*Senate Committees*, 2019).

To argue the instrument's orthogonality to omitted variables, it is necessary to discuss the criteria of choosing members inside the committee. Each party determines a list of members as potential members in the committee. Then, the Senate's full body chooses the members of each committee according to the senate's rules. The selection process prefers the senators who have served before in the Congress, House service, and the governor. Previous experience in public service and having an old age give the senators big advantages to be chosen in senate appropriation committee. Therefore, the selection process does not depend on a state's characteristics such as current economic growth or population. It depends on the personal characteristics of the members (*Senate Committees*, 2019).

The longer time in public service results in more possibility to be chosen as a member of the committee. Moreover, the senators leave the committee only if they retire or die (Slavtchev & Wiederhold, 2016). Controlling for many control variables ensures that the impact of the number of senators in senate appropriation committee on high-tech exports is only through R&D public procurement. In the next sections, tables show that IV results are robust to include such control variables.

Using state and year fixed effects, the main basic OLS result suggests that an increase by 1% in R&D public procurement induces an increase in high-tech exports by 4.9%. Regarding the IV approach, the first stage results suggest that there is a strong and positive correlation at 1% between the number of senators in the senate appropriation committee and R&D public procurement. The second stage results suggest that there is a strong and positive impact of R&D public procurement on high-tech exports. The Kleibergen-Paap F statistics is greater than 10 so there is no weak instrument. Also, Durbin-Wu-Hausman tests indicate no statistically significant difference between the FE and the IV estimator.

I check the robustness by using many controls such as company R&D expenditure, FDI, patent, U.S. population, state real GDP, GDP growth rate of high-tech industries, university R&D expenditure, federal R&D expenditure, and graduates in science and engineering with including time and state fixed effect and clustered standard error at the state level. Moreover, I use the linear and quadratic time trend to control for economic shocks which may drive results. I also test whether the relationship between the R&D procurement and exports is driven by outliers. Then, I exclude outliers. I use an alternative measure of the dependent variable which is the exports as a share of GDP. The OLS and IV results are robust to all these robustness checks. Hence, evidence from a variety of identification strategies suggests that the relationship is causal. The paper proceeds as follows: Section 2 introduces the theoretical framework. Section 3 presents the data. Section 4 provides the empirical strategy. Section 5 reports the results. Section 6 presents the robustness check. Section 7 discusses the summary of results, policy implications, and avenues for future research.

2 Theoretical framework

2.1 R&D public procurement as a technology policy

The most related literature is about the effect of total public and private R&D expenditure on high-tech exports. Regarding the macro-level evidence, there are numerous studies find a positive relationship between R&D expenditure and exports. For example, Braunerhjelm and Thulin (2008) examine market size and differences in the institution among countries while they study the effect of R&D expenditures on high-tech exports. They contribute to the literature by constructing a theoretical model. They argue that an increase in R&D expenditures by one percentage point implies a three-percentage-point increase in high-technology exports in 19 OECD countries between 1981 and 1999. The market size has no significant effect. Institutional factors have a significant effect on the dynamics of export.

However, Kizilkaya et al. (2016) examine the relationship between R&D expenditures, patent, openness, and exports by using panel fully modified OLS and dynamic OLS in Brazil, Russia, India, China, and Turkey. They start the empirical analysis with testing the stationarity of the variables using Im, Pesaran, and Shin (IPS) test for panel unit root test. Results show that R&D expenditures and openness have positive impacts on high- tech export.

Regarding micro data, most evidence suggests the positive relation between R&D expenditure and high-tech exports (Basile (2001),Pla-Barber and Alegre (2007)). For instance, Zhao and Li (1997) examine the interactions between R&D expenditure, firm size, and capital intensity when they study the effect of R&D expenditure on high-tech exports. They analyze the impact of R&D expenditure on export growth in 1551 manufacturing firms in China. Using logistic and simultaneous analyses, results confirm the significant and positive impact of R&D on export. Smith et al. (2002) show that the endogeneity issue is not addressed well in previous studies. So, they use full information maximum likelihood method estimation with bivariate Probit specification with using a sample of 3,500 Danish firms to identify the causal effect of R&D expenditure and high-tech exports. They use data of the 1997 R&D survey. Results show that R&D is an important factor for being an exporting firm. On the other hand, some empirical evidence shows the weak and insignificant relationship between R&D expenditure and high-tech exports (Lefebvre et al. (1998), Fu et al. (2011)).

Many types of R&D expenditure have been discussed such as subsidies in terms of their effect on exports and productivity. For example, Fang et al. (2018) discuss the effect of government R&D subsidies on firm performance including the exporting behavior. Using difference in difference, Fang et al. (2018) compare before and after changes in public subsidies on firm performance when the Chinese government has launched a program against corruption. Results show that such changes in subsidies due to the program have a statistically significant and positive effect on exports and firm performance.

Moreover, a growing body of empirical studies show the positive effect of public procurement on innovation. Many studies suggest that the public demand can be a major source of technological change (Mowery and Rosenberg (1979), Dosi (1982), Von Hippel (2007), Malerba et al. (2007), Rogers (1995), Fontana and Guerzoni (2008), Guerzoni (2010)). Regarding the theoretical literature dedicated to public procurement, Bresnahan and Trajtenberg (1995) confirm the positive effect of public procurement on technology adoption by reducing market failures,and technological uncertainties.

Aschhof and Sofka (2009) analyze different public policy tools such as R&D subsidies, innovative public procurement, regulation, and university research expenditure. They use German firm-level data. They suggest that public procurement is more influential for the innovation of small-size firms. Also, Guerzoni and Raiteri (2015) analyze different public policy tools of public contracts, R&D subsidies, and tax credits on private innovation. They suggest that there is a positive effect on public procurement on innovation.

Defense-oriented procurement has largely influenced the dynamics of technological change during the 20th century, especially in the United States. Previous empirical evidence shows that the R&D procurement for purposes of national defense has stimulated technological progress in the semiconductor, the computer, and the aviation industry (D. Mowery & Rosenberg, 1982). In the early stages of their development, Several empirical works (Mowery and Rosenberg (1989), Langlois and Steinmueller (1999), Mowery (2011)) shows that the semiconductor sector as one of the high-tech industries in the USA has boomed due to large procurement contracts between the public and private sectors. Post-cold war era, Cowan and Foray (1995) show that R&D investment-oriented for defense purposes has played an important role in technological change.

2.2 Mechanisms

The demand-side factors have little been discussed in economic theory, which largely discussed supply-side factors enhancing innovation. Previous empirical evidence has strongly shown that demand-side factors stimulate innovation (Kleinknecht (1999), Slavtchev and Wiederhold (2016)) . However, previous studies have no theoretical or empirical discussions regarding the effect of public procurement on high-tech exports. Such relation can be explained by many mechanisms.

First, the public sector can facilitate the adoption of high-tech products by becoming the first mover. It can adopt technology early and take the risk through purchases. The public sector can act as a lead user in high-tech industries. Moreover, it can provide producers with valuable information about market needs and requirements, and meet the existent demand of products or services (Dalpé et al. (1992), von Hippel (1986)). In fact, the public procurement can upgrade sectors characterized by greater technological intensity. So, the public procurement can be considered as a key industrial policy tool to increase high-tech exports.

Second, public procurement can guarantee a minimum level of market size that allows firms to have early economies of scale, compensate costs, and reduce the risks involved with producing high-tech products. The scale of demand can be influential in those industries characterized by heavy R&D requirements, high costs or high levels of uncertainty (Porter, 1990).

Thirdly, the public sector might spur domestic competition in an industry or sector. As a result, firms that are exposed to more competition in domestic markets are more likely to succeed in international markets. Increasing competition in domestic markets might induce firms to adopt more efficient and cleaner production techniques, which in turn facilitates entry into foreign markets. Furthermore, firms might adopt cost-cutting operations, which would increase the competitiveness of the firms and, most likely improve their performance in the international market and their export share.

Furthermore, the public sector can be demanding and sophisticated and reflect the international needs in its purchases. So, it spurs firms to be more innovative and produce high-tech products and export them. Following high international standards can lead firms be more competitive in foreign markets. Firms that sell products to the public sector might have advantages compared to other firms. Supplying to the public sector may grant firms reputation or learning benefits that can give supplier firms a competitive advantage in foreign markets(Uyarra et al., 2014).

Moreover, market failures might exist due to poor interaction between producers and customers. Information asymmetry might exist where producers are not aware of customer demand and what product and service innovation the market can offer (Edler & Georghiou, 2007). The public procurement can reduce technological uncertainty by offering guidance for private suppliers to propose innovative solutions. Furthermore, public demand can test the ground of the innovation results, and feed-backs. Such help offered by the public sector can spur suppliers to modify well the processes of the innovations (Uyarra et al., 2014). The public sector purchases can create trust, reduce transaction costs, and eliminate information asymmetries. When certain products are publicly procured, consumers would change their purchase choices into more innovative products guaranteed by the government.

Clearly, I argue here that R&D public procurement supports the adoption of technology by firms. I hypothesize that public procurement, by stimulating additional innovation, would increase the exporting of high-tech sectors. Public procurement as a type of such expenditure receives less attention despite its great success in supporting exports in the real world. This lack of discussion provides a strong incentive to study public procurement. So, I contribute to the recent discussions documenting the relationship between public R&D expenditure and high-tech exports in a number of ways. First, I investigate a new type of public expenditure (public procurement) in terms of its effect on high-tech exports. Second, I provide new evidence in the USA at the state level since it is the largest purchaser of goods and services. Third, the paper solves the endogeneity problem by using a new instrumental variable to identify the causal effect of R&D public procurement on high-tech exports.

3 Data

3.1 High-tech-exports

The main dependent variable is high-tech exports of 50 U.S. states and the District of Colombia. I obtain it from the United States Census Bureau which is the official source and responsible for reporting the US export and import statistics. To construct the data at the state level, I aggregate values in constant US dollar of exports in high-tech industries, using the NAICS information and the high-tech industry definition of the Bureau of Labor Statistics (Hecker, 2005). Table 2 shows the high-tech sectors with NAIC classifications. Table 1 shows summary statistics of the data.

3.2 Public procurement

I use administrative data on public procurement contracts in the United States constructed by Slavtchev and Wiederhold unique dataset. It uses the federal procurement data system-next generation (FPDS-NG), provided by the general services administration (GSA)(Goldman, Rocholl, & So, 2013). The FPDS-NG database includes about 21.5 million contract actions. Data are aggregated by type of industry, state, and year. The data covers more than 98 percent of all federal procurement actions of agencies. It contains information about the contract volume (in current USD), dates, the place of performance, whether or not the contract is oriented for R&D.

3.3 Other controls

Many control variables are used since they might be associated with R&D public procurement and high-tech exports. The set of control variables include FDI, real GDP of state, population, GDP growth rate of high-tech industries, university expenditure on R&D, graduates in science and engineering, federal expenditure on R&D, private R&D expenditure, federal aid to state, and utility patent counts. I obtain data on FDI from the U.S. Bureau of Economic Analysis (BEA) which shows activities of U.S. affiliates of foreign parents and their financial operations. FDI includes gross property, plant, and equipment of foreign affiliates at 50 U.S. State and the District of Colombia.

Data on population, GDP growth rate of high-tech industries, and the real GDP of state is obtained from the U.S. Bureau of Economic Analysis (BEA). The state-specific deflator of the year 2000 is used to deflate GDP (Slavtchev & Wiederhold, 2016). The gross domestic product estimated by BEA includes the value of the goods and services produced in the United States. GDP also measures the value and makeup of the US output, the types of income generated, and how that income is used. BEA estimates GDP quarterly and annually. The BEA data includes breakdowns of industries contributions to each of these economies.

All R&D expenditures data are converted into constant dollars ,as well as, using the GDP deflator of the year 2000 (Slavtchev & Wiederhold, 2016). I employ data on university expenditure on R&D from the US Survey of Industrial R&D (SIRD), administered by the National Science Foundation (NSF). University expenditure on R&D is funded by the federal government, state and local government, businesses, and other organizations. the National Science Foundation (NSF) collect data through the Higher Education Research and Development Survey which is a major source of data on R&D expenditures at U.S. colleges and universities. The survey collects information on R&D expenditures by field of research and source of funds. It collects information on types of research, expenses, and headcounts of R&D personnel. The survey is an annual census of institutions which its expenditures are about at least $150,000 allocated for R&D in the fiscal year.

I utilize data on graduates in science and engineering from the National Science Foundation (NSF) data, used by Slavtchev and Wiederhold unique dataset.The NSF uses Survey of Graduate Students and Post-doctorates in Science and Engineering. It is an annual census of all U.S. academic institutions granting research-based master's degrees or doctorates in science, engineering, and selected health fields as of fall of the survey year. The survey, sponsored by the National Center for Science and Engineering Statistics within the National Science Foundation and by the National Institutes of Health, collects the total number of master's and doctoral students, postdoctoral appointees, and doctorate-level non-faculty researchers by demographic and other characteristic such as source of financial support.

Data on federal expenditure on R&D is provided by the US Survey of Industrial R&D (SIRD), administered by the National Science Foundation (NSF). Federal aid to state is defined as the local and federal government grants to state and local governments (Slavtchev and Wiederhold, 2016). I use data from the US Census Bureau which includes all federal assistance to states. All monetary variables are measured in constant USD with the base year of 2000. It includes the amount of money expended directly to State, local and territorial governments in the form of grants and other payments for the purpose of stimulating R&D.

Data on private R&D expenditure is provided by the US Survey of Industrial R&D (SIRD), administered by the National Science Foundation (NSF). The NSF surveys a stratified representative sample of firms with five or more employees to collect information on all domestically performed R&D expenditures by the source of funding (private and public) and state of performance. I use data on utility patent counts from the U.S.

patent and trademark office. I use Data on the number of senators in senate appropriation committee (instrumental variable) from Slavtchev Wiederhold unique dataset.

4 Empirical strategy

4.1 An OLS approach

The objective of the paper is to examine the effect of R&D public procurement on high-tech exports in the USA. The paper applies an OLS and instrumental variable estimation. The dependent variable is the aggregated U.S. exports of high-tech industries of 50 states and the District of Colombia from 1999 to 2009. The main independent variable is R&D public procurement at the state level. Equation (1) provides the starting point for the econometric analysis of the impact of R& D public procurement on high-tech exports. I cluster standard errors at the state level.

$$log(high - tech\ exports)_{it} = \alpha + \beta_1 log(\ R\&D\ public\ procurement)_{it} +$$

$$\beta_2 log(X)_{it} + \epsilon_i + \nu_t + u_{it}$$

(1)

$high - tech\ exports_{it}$ denotes the amount of high - tech exports in state i and year t. $R\&D\ public\ procurement_{it}$ denotes the R&D public procurement in state i and year t. To alleviate any confounding factors which may drive the results, X_{it} denotes a set of state-level covariates which include private expenditure on research and development, utility patent counts, FDI, university expenditure on research and development, federal expenditure on research and development,state real GDP, GDP growth rate of high-tech industries, population, and the number of graduates in science and engineering. Equation (1) contains a state fixed effects, ϵ_i , which controls for unobserved state characteristics that are constant over time. Using state fixed effect confirms that unobservable state time-invariant specific factors do not drive the correlation between high-tech exports and R&D public procurement. In addition, using time fixed effect, ν_t, controls for unobserved factors which affect all states such as business cycles and national policy changes. The error term is denoted by u_{it}.

4.2 An Instrumental Variable approach

The paper starts with estimating equation (1) by the OLS approach. However, this estimation is biased because there might be further unobserved factors that are associated with both R&D public procurement and high-tech exports. For example, the number of federal procurement contracts might depend on a variety of unobserved state characteristics such as policy changes and regulations which are related to exports. Furthermore, reverse causality problem arises since high-tech exports of firms attract more public procurement. To address the concern of the endogeneity, I perform an instrumental-variable (IV) approach. I use the exogenous variation of public procurement from the senate appropriation committee to identify the causal effect of R&D public procurement on high-tech exports. I use an instrument that is correlated with the amount of R&D public procurement but uncorrelated with any state characteristics that may affect high-tech exports. In this section, I undertake other strategies to assess the causal impact of procurement on high-tech exports. First, I control for observable factors that may be associated with the procurement and exports. The validity of this approach relies on the assumption that using control variables mitigates omitted variable bias. Second, I mitigate the omitted variable bias by including state and time fixed effects which control for unobservable characteristics.

4.2.1 The correlation between R&D public procurement and the number of senators in senate appropriation committee

The number of senators in the appropriation committee leads to more amount of public procurement as a total. States, which have representatives in senate appropriation committee, are expected to have more public procurement contracts and appropriations compared to states with no representative senators in the committee. Only the senators in the appropriation committee have the ability to affect the amount of public procurement. The full appropriations committee consists of twelve subcommittees. The main role of the twelve subcommittees is to authorize the appropriations according to the senate budget decisions. Each senator wants to get the larger amount of procurement for his state (*Senate Committees*, 2019). All first stage tables show that there is a positive and significant correlation between the number of senators in the senate appropriation committee and the R&D public procurement. It implies that I have a relevant instrument.

4.2.2 The instrument's orthogonality to omitted variables

To argue that the instrument is exogenous, it is necessary to know how senators are selected inside the appropriation committee and the criteria of appointment inside the committee. Each party determines a list of members as potential members in the committee. Then, the senate's full body chooses the members of each committee according to the Senate's rules. Previous experience in public service is an important factor in the selection. Moreover, the old age gives a big advantage to be chosen as a member of the committee. Hence, the selection process of senators in the senate appropriation committee does not depend on a state's characteristics such as current economic growth or population. It depends on the personal characteristics of members (*Senate Committees*, 2019).

The longer time in public service results in more possibility to be chosen as a member in the committee. Moreover, the senators leave the committee only if they retire or die(Slavtchev & Wiederhold, 2016). Controlling for many control variables ensures that the impact of the number of senators in senate appropriation committee on high-tech exports is only through R&D public procurement. In the next sections, tables show that IV estimates are robust to include such control variables.

5 Results

This section shows the baseline results of the empirical analysis. I start by providing a visual description of the relationship between R&D public procurement and high-tech exports. Figure 1 shows a visual inspection of the relationship between the R&D public procurement and high-tech exports for each state individually. It is clear that both variables follow similar positive patterns in the majority of states. Moreover, the scatter plot in figure 2 shows that there is a positive correlation between R&D public procurement and high-tech exports in the USA. In all specifications of the analysis, I include time and state fixed effect to absorb unobserved characteristics which may drive results. Moreover, I use clustered standard error at the state level. Estimates of equation (1) are reported in Table 3. In column 1, I control for R&D public procurement and FDI since it may lead to a spurious correlation between the relationship between R&D public procurement and high-tech exports. The estimated coefficient for R&D public procurement, β_1, is positive and statistically significant. The increase in R&D public procurement by 1% implies an increase in high-tech exports by 4.9%.

In the IV results, the column 1 of table 8 shows the main basic IV result. I control for FDI, federal R&D expenditure, and university R&D expenditure to rule out two potential threats. The first potential threat is that both FDI and public procurement affect high-tech industries. Thus, not controlling for FDI might lead to falsely attributing its effects to public procurement. The second potential threat is that results are driven by other types of government or university expenditure. The increase in R&D public procurement by 1% implies an increase in high-tech exports by 16.4%. For all first stage tables, the Kleibergen-Paap F statistics is greater than 10 which implies that I can reject the possibility of weak instruments. The Kleibergen-Paap F statistics is used when standard errors are not assumed to be i.i.d. For all second stage tables, Durbin-Wu-Hausman tests indicate no statistically significant difference between the FE and the IV estimator.

6 Robustness checks

6.1 OLS Robustness checks

Regarding the OLS results, estimates of equation (1) are reported in Table 3. In column 2 of table 3, I control for R&D public procurement and federal R&D expenditure since there are other potential confounders, such as other types of government expenditure, may confound results. The estimated coefficient for R&D public procurement remains positive and statistically significant. Specifically, the increase in R&D public procurement by 1% implies an increase in high-tech exports by 4.5%. Across specifications, The coefficient of R&D public procurement remains virtually unchanged. Controlling for federal R&D expenditure decreases the magnitude of the estimated coefficient by only 0.4%.

In column 3, I control for company R&D expenditure. The estimated coefficient for R&D public procurement remains positive and statistically significant. Specifically, the increase in R&D public procurement by 1% implies an increase in high-tech exports by 5%. Controlling for company R&D expenditure increases the magnitude of the estimated coefficient by only 0.1%.

In column 1 of Table 4, I control for federal aid to state, FDI, and R& D public procurement since OLS results would be biased if the other types of government expenditure lead superious correlation between public procurements and high-tech exporting. The estimated coefficient for R&D public procurement, β_1 , is positive and statistically significant. Specifically, the increase in R&D public procurement by 1% implies an increase in high-tech exports by 5.1%. In column 2 of table 4, I additionally include graduates in science and engineering since they may drive results. The estimated coefficient for R&D public procurement, β_1 shows that results are still robust.

In column 3 of table 4, I include GDP growth rate of high-tech industries since the growth of high-tech industries in a state may imply more procurement contracts with government and more exports. The estimated coefficient for R&D public procurement, β_1 , remains positive and statistically significant. Specifically, the increase in R&D public procurement by 1% implies an increase in high-tech exports by 5%. Controlling for GDP growth rate of high-tech industries and FDI increases the magnitude of the estimated coefficient by only 0.1%. Estimates of equation (1) are reported in table 5 using university expenditure on research and development, patent counts, and GDP of states. In column 1 of table 6, I replace the year dummies with a time trend (linear and quadratic) to control for any economic shock.

In column 2 of table 6, I check robustness by using high-tech exports as a share of GDP as an alternative measure of the dependent variable. In column 1 of table 7, I jointly include all control variables together. The increase in R&D public procurement by 1% implies an increase in high-tech exports by 5%. Controlling for all variables increases the magnitude of the estimated coefficient by only 0.1%. Across these specifications, the estimated coefficient for R&D public procurement, β_1 , remains positive and statistically significant.

Figure 3 shows the leverage and the normalized residuals squared. It is used as a method to detect outliers. The far observations on the vertical line present the observations with high influence over the regression. The far observations on the horizontal line have high residuals. As it is clear, Iowa, Hawaii, New Hampshire, Kansas, South Carolina, California, Mississippi, Arkansas are the outliers. In table 7(column 2), I remove outliers to ensure that no specific observation drives results. The increase in R&D public procurement by 1% implies an increase in high-tech exports by 3.9%. The magnitude decreases by only 1%. All of the previous specifications show that there is a positive and significant result but it is still biased since there might be spurious correlation and reverse causality problem.

6.2 IV Robustness checks

In columns 2 & 3 of table 8 Panel A, I use different controls such as US population and GDP of states to rule out any confounders which simultaneously lead to larger amount of R&D public procurement and high-tech exports. Coefficient of R&D procurement has a small change however it remains positive and significant (16.4% in column 2, 15.4% in column 3). The first stage results of the IV approach show that there is a relevant instrument since there is a strong and positive correlation between R&D public procurement and the number of senators in senate appropriation committee.

In column 1 of table 9 (panel A second stage), I control for R&D public procurement, FDI, federal R&D expenditure, and GDP growth rate of high-tech industries, and federal aid to state to alleviate the possibility that the growth of high-tech industries in a state may induce a larger amount of procurement contracts with government and more exports. The estimated coefficient for R&D public procurement is positive and statistically significant. The increase in R&D public procurement by 1% implies an increase in high-tech exports by 18.1%. The magnitude of the estimated coefficient increases by only 1.7%. In column 2 of table 9 (panel A second stage), I add a different co-variate which is patent to rule out that there are further confounding factors omitted from the analysis. Coefficient of R&D procurement remains virtually unchanged.It is still positive and significant (15.4%).

In column 1 of table 10 (panel A second stage), I control for R&D public procurement, FDI, university R&D expenditure, and company R&D expenditure. Adding company R&D expenditure is to rule out the possibility that private R&D expenditure might lead to falsely attributing its effects to public procurement. In the second and third columns, I add different controls which are federal aid to state and graduates in science and engineering. The estimated coefficients for R&D procurement in the three columns changes by 2%, however, it remain positive and significant. In table 11 (panel A second stage), I jointly use all control variables. The estimated coefficient for R&D public procurement remains positive and statistically significant. Specifically, the increase in R&D public procurement by 1% implies an increase in high-tech exports by 16.9%.

In column 1 of table 12 (panel A second stage), I control for R&D public procurement, FDI, university R&D expenditure, federal R&D expenditure, and GDP of states. Moreover, I replace the year dummies of linear and quadratic time trend to control for any economic shocks. The estimated coefficient for R&D public procurement remains positive and statistically significant. Specifically, the increase in R&D public procurement by 1% implies an increase in high-tech exports by 15.4%. The magnitude decreases by only 1%. In column 2 of table 12 (panel A second stage), I remove outliers such as Iowa, Hawaii, New Hampshire, Kansas, South Carolina, California, Mississippi, Arkansas are the outliers. Removing outliers is to ensure that no specific observation drives results. The estimated coefficient for R&D public procurement remains positive and statistically significant. The increase in R&D public procurement by 1% leads to an increase in high-tech exports by 19.8%. Results are still positive and significant. In column 1 of table 12 (panel A second stage), I use the dependent variable as a share of GDP. The estimated coefficient for R&D public procurement remains positive and statistically significant. The increase in R&D public procurement by 1% leads to an increase in high-tech exports by 17.9%.In all specifications, the estimated coefficient on the R&D public procurement remains virtually identical to that in the baseline specifications. Results prove the robustness of the baseline FE results to further R&D determinants and various sources of spurious correlation.

7 Conclusion

Using a unique panel dataset, I estimate the effect of R&D public procurement on high-tech exports at the united state level in the period 1999 to 2009. I fill the gap in previous studies in many ways. First, I discuss a new type of R&D public expenditure (public procurement). Second, I show a new empirical study in the USA at the state level since it is the largest purchaser of goods and services in the world. Third, I address the endogeneity problem by employing a new instrumental variable to identify the causal effect of R&D public procurement on high-tech exports. To introduce a causal interpretation of the impact of R&D public procurement on high-tech exports, the empirical analysis uses two main strategies; OLS and IV approach with the inclusion of many covariates. The OLS estimates show that there is a positive and significant impact of R&D public procurement on high-tech exports. The main basic OLS result suggests that an increase by 1% in R&D public procurement induces an increase in high-tech exports by 4.9%. The IV approach uses the number of senators in the Senate appropriation committee as an instrument for the R&D public procurement. Regarding the IV estimation, the first stage results show that there is a positive correlation between the number of senators in the senate appropriation committee and the R&D public procurement. The second stage results confirm the causal interpretation of R&D public procurement on high-tech exports.

Moreover, robustness checks include replacing the year dummies with a time trend, excluding outliers, and taking the exports as a share of GDP. Results are robust to include many controls with including time and state fixed effect and clustered standard error at the state level. According to these findings, the main policy implication is to use purchases from high-tech industries as a public policy tool to induce firm innovation process and to motivate those firms to increase high-tech exports. Providing a guaranteed public demand can imply a great incentive for companies to spend on scientific research and improve innovation performance which has a positive effect on high-tech exporting. Public procurement includes the promotion of advanced industries, which create rapid growth and technological progress (Vonortas et al, 2015). The government should favor R&D public procurement rather than non-R&D public procurement. The presence of significant and tangible effect of R&D public procurement on high-tech exports further suggests that any increase in public demand should be associated with a refinement of policies of trade openness and technology adoption facilitation by firms. Further research can analyze the relationship between R&D public procurement and high-tech exports in the USA at firm and industry level. Future research should provide an instrument at the firm & industry level.

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8 Tables and figures

Table 1: the descriptive statistics

	(1)				
	mean	sd	min	max	count
High-tech exports(billion)	4.881	8.960	0.008	66.900	561
R&D public procuremnt(billion)	0.592	1.186	0.0001	8.879	510
FDI(ten billion)	2.107	2.200	0.068	12.842	448
Real GDP of state (million deflated)	0.224	0.258	0.016	1.593	561
University R&D expenditure(billion)	0.518	0.618	0.018	3.761	561
Graduates in Science & Engineering(thousand)	9.613	11.532	0.572	68.039	561
Federal R&D expenditure(billion)	0.362	0.736	0.0008	5.222	521
GDP growth rate of high tech industries(%)	-1.679	1.034	-6.492	0.303	555
Federal Aid to State(million)	7.069	7.899	0.778	43.525	561
Company R&D expenditure(billion)	3.802	6.687	0.019	49.616	525
Patent (thousand)	1.760	2.991	0.018	22.275	550
The number of senators	0.559	0.507	0.000	2.000	511
Population(million)	5.748	6.403	0.491	36.961	561

Table 2: high-tech industries

4 digit NAIC code	Description
3254	Pharmaceutical and medicine manufacturing
3341	Computer and peripheral equipment manufacturing
3342	Communications equipment manufacturing
3344	Semiconductor and other electronic component manufacturing
3345	Navigational, electro-medical, and instruments manufacturing
3364	Aerospace product and parts manufacturing
5112	Software publishers

Notes: High-tech industries follow the classification of the US Bureau of Labor Statistics (Hecker, 2005)

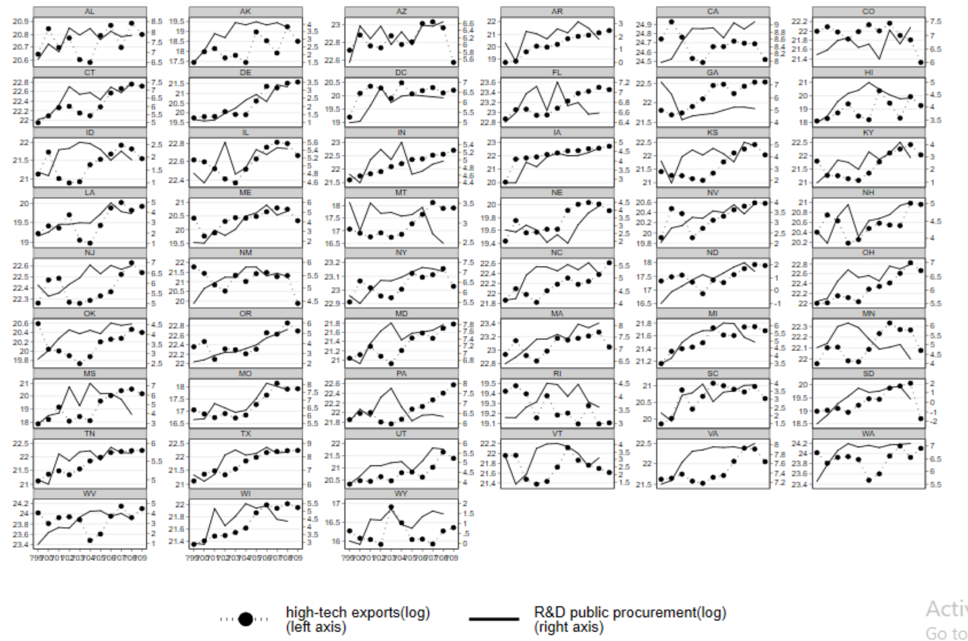
Table 3 : OLS

Dependent Variable: high-tech exports			
	(1)	(2)	(3)
R&D Procurement	0.049*	0.045*	0.050*
	(0.029)	*(0.026)*	*(0.028)*
FDI	0.084		
	(0.081)		
Federal R&D expenditure		0.022	
		(0.028)	
Company R&D expenditure			–0.038**
			(0.016)
Observation	448	472	474
R-squared	0.34	0.41	0.42

Notes: OLS Approach using the time and state fixed effect. The dependent variable is High-tech exports.

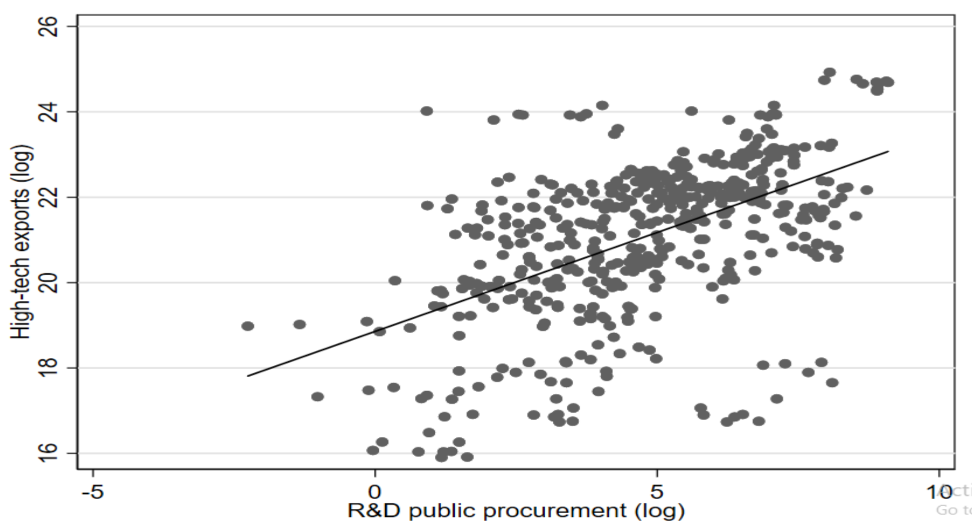
I cluster the SE (shown in parentheses) at state level. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: high-tech exports and R&D public procurement of 50 united states and DC



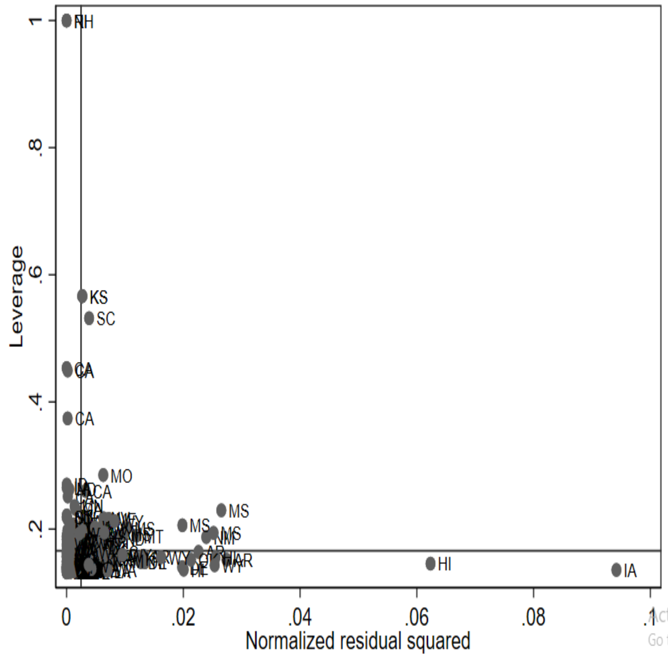
Notes: The figure represents high-tech exports and R&D public procurement share across the 50 united states and DC.

Figure 2 : Scatter plot



Notes: The figure represents high-tech exports and R&D public procurement across the 50 united states and DC.

Figure 3: Method used to detect Outliers



Notes: The lines on the chart show the average values of leverage and the (normalized) residuals squared.

Table 4: OLS

Dependent Variable: high-tech exports			
	(1)	(2)	(3)
R&D Procurement	0.051*	0.051*	0.050*
	(0.029)	*(0.030)*	*(0.029)*
FDI	0.079	0.086	0.076
	(0.079)	*(0.082)*	*(0.083)*
Federal Aid to State	0.379		
	(0.343)		
Graduates in Science&Engineering		0.124	
		(0.307)	
GDP growth rate of high-tech industry			0.144
			(0.289)
Observation	448	448	444
R-squared	0.35	0.34	0.34

Notes: OLS Approach using the time and state fixed effect. The dependent variable is High-tech exports.

I cluster the SE (shown in parentheses) at state level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: OLS

Dependent Variable: high-tech exports	(1)	(2)	(3)
R&D Procurement	0.049*	0.062**	0.055**
	(0.029)	*(0.027)*	*(0.026)*
FDI	0.084	0.094	0.091
	(0.082)	*(0.087)*	*(0.085)*
University R&D expenditure	–0.020		
	(1.981)		
Patent		–0.500	
		(0.509)	
Federal R&D expenditure		0.025	0.027
		(0.031)	*(0.031)*
GDP of state			–0.166**
			(0.077)
Observation	448	404	413
R-squared	0.34	0.37	0.37

Notes: OLS Approach using the time and state fixed effect. The dependent variable is High-tech exports.

I cluster the SE (shown in parentheses) at state level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: OLS: using a different measure of dependent variable and year trend

Dependent Variable: high-tech exports	(1)	(2)
R&D Procurement	0.052*	0.062**
	(0.030)	*(0.027)*
FDI	0.136*	0.012
	(0.080)	*(0.007)*
Federal R&D expenditure	0.020	0.029
	(0.034)	*(0.027)*
Patent	–0.570	–0.047
	(0.413)	*(0.037)*
University R&D expenditure	0.067	0.037
	(2.761)	*(0.198)*
Observation	404	404
R-squared	0.34	0.13
replace year dummies with year trend	yes	no
dependent var as share of GDP	no	yes

Notes: I cluster the SE (shown in parentheses) at state level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: OLS

Dependent Variable: high-tech exports		
	(1)	(2)
R&D Procurement	0.050*	0.039*
	(0.029)	*(0.023)*
Federal Aid to State	0.468	–0.126
	(0.493)	*(0.171)*
Graduates in Science&Engineering	0.240	0.299
	(0.316)	*(0.198)*
Federal R&D expenditure	0.029	
	(0.031)	
US Population	3.955	5.028***
	(2.648)	*(1.132)*
GDP of state	–0.138	
	(0.099)	
FDI	0.070	
	(0.086)	
University R&D expenditure	0.143	
	(0.209)	
GDP growth rate of high tech industry	0.137	–0.127
	(0.319)	*(0.130)*
Patent	0.167	0.459
	(0.532)	*(0.571)*
Company R&D expenditure	–0.021	–0.024
	(0.018)	*(0.020)*
Observation	404	402
R-squared	0.39	0.50
All controls	yes	no
Remove outliers	no	yes

Notes: OLS approach using all control variables. OLS Approach uses time and state fixed effect . *** p<0.01, ** p<0.05, * p<0.1

Table 8 Panel A: IV Approach: Second Stage

Dependent Variable: high-tech exports	(1)	(2)	(3)
R&D Procurement	0.164**	0.164**	0.154*
	(0.081)	*(0.081)*	*(0.087)*
Federal R&D expenditure	0.027	0.027	0.026
	(0.027)	*(0.027)*	*(0.027)*
FDI	0.114**	0.114**	0.106*
	(0.055)	*(0.055)*	*(0.055)*
University R&D expenditure	–0.018	–0.018	
	(0.225)	*(0.225)*	
US Population		4.286***	
		(1.328)	
GDP of state			–1.367*
			(0.747)
Observation	411	411	411
R-squared	0.01	0.18	0.01
DW Hausman Test	0.275	0.275	0.3463

Table 8 Panel B : IV Approach : First Stage

Dependent Variable: R&D Procurement	(1)	(2)	(3)
the number of senators	0.482***	0.482***	0.446***
	(0.145)	*(0.145)*	*(0.138)*
Federal R&D expenditure	0.029	0.029	0.027
	(0.057)	*(0.057)*	*(0.066)*
FDI	–0.070	–0.070	–0.087
	(0.124)	*(0.124)*	*(0.137)*
University R&D expenditure	1.386***	1.386 ***	
	(0.319)	*(0.319)*	
US Population		7.838***	
		(2.491)	
GDP of state			-2.829*
			(1.553)
Observation	411	411	411
Kleibergen-Paap F statistic	11.009	11.009	10.375

Notes: 2SLS. The dependent variable in the first stage is R&D Public procurement. The dependent variable in the second stage is High-tech exports. The instrumental variable is the number of senators. All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. *** p<0.01, ** p<0.05, * p<0.1

Table 9 Panel A: IV Approach: Second Stage

Dependent Variable: high-tech exports	(1)	(2)
R&D Procurement	0.181*	0.154**
	(0.101)	*(0.077)*
Federal R&D expenditure	0.032	0.023
	(0.027)	*(0.026)*
FDI	0.098**	0.107*
	(0.044)	*(0.054)*
GDP growth rate of high-tech industries	0.084	
	(0.252)	
Patent		–0.611*
		(0.356)
Federal aid to state	0.462	
	(0.396)	
Observation	407	402
R-squared	0.012	0.004
DW Hausman Test	0.342	0.339

Table 9 Panel B: IV Approach: First Stage

Dependent Variable: R&D Procurement	(1)	(2)
the number of senators	0.457***	0.466***
	(0.143)	*(0.146)*
Federal R&D expenditure	0.025	0.037
	(0.063)	*(0.064)*
FDI	–0.047	–0.073
	(0.134)	*(0.147)*
GDP growth rate of high-tech industries	–0.250	
	(0.284)	
Patent		1.364
		(1.401)
Federal aid to state	–0.256	
	(0.423)	
Observation	407	402
Kleibergen-Paap F statistic	10.153	10.143

Notes: Two-stage least squares estimation. The dependent variable in the first stage is R&D Public procurement. The dependent variable in the second stage is High-tech exports. The instrumental variable is the number of senators a state has on the US Senate Appropriations Committee. All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. SE is robust to panel (state) heteroskedasticity and within-state autocorrelation. *** p<0.01, ** p<0.05, * p<0.1

Table 10 Panel A: IV Approach: Second Stage

Dependent Variable: high-tech exports	(1)	(2)	(3)
R&D Procurement	0.136*	0.170**	0.180**
	(0.082)	*(0.077)*	*(0.089)*
University R&D expenditure	–0.007	–0.034	–0.027
	(0.212)	*(0.215)*	*(0.247)*
Federal R&D expenditure		0.024	0.029
		(0.026)	*(0.027)*
FDI	0.111*	0.116**	0.108**
	(0.058)	*(0.053)*	*(0.049)*
Company R&D expenditure	–0.036***		
	(0.011)		
Graduates in Science&Enginerring		0.295	
		(0.355)	
Federal Aid to State			0.373
			(0.260)
Observation	411	411	411
R-squared	0.011	0.011	0.01
DW Hausman Test	0.359	0.262	0.2602

Table 10 Panel B: IV Approach: First Stage

Dependent Variable: R&D Procurement	(1)	(2)	(3)
the number of senators	0.469***	0.468***	0.482***
	(0.145)	*(0.141)*	*(0.145)*
University R&D expenditure	1.361***	1.427***	1.387***
	(0.312)	*(0.294)*	*(0.320)*
Federal R&D expenditure		0.042	0.029
		(0.052)	*(0.057)*
FDI	–0.071	–0.078	–0.070
	(0.123)	*(0.112)*	*(0.124)*
Company R&D expenditure	–0.032*		
	(0.017)		
Graduates in Science&Enginerring		–1.456*	
		(0.616)	
Federal Aid to State			0.025
			(0.243)
Observation	411	411	411
Kleibergen-Paap F statistic	10.437	11.001	10.957

Notes: 2SLS. The dependent variable in the first stage is R&D Public procurement. The dependent variable in the second stage is High-tech exports. The instrumental variable is the number of senators. All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. *** p<0.01, ** p<0.05, * p<0.1

Table 11 Panel A: IV Approach: Second Stage

Dependent Variable: high-tech exports	
	(1)
R&D Procurement	0.169**
	(0.077)
Federal Aid to State	0.415
	(0.409)
Graduates in S&E	0.386
	(0.337)
Federal R&D expenditure	0.017
	(0.026)
US Population	1.175
	(2.262)
GDP of state	0.989
	(0.913)
FDI	0.099**
	(0.045)
University expenditure	–0.024
	(0.219)
non RD procurement	0.069
	(0.085)
Patent	–0.438
	(3.25)
Firm R&D expenditure	–0.018
	(0.016)
Observation	402
R-squared	0.19
DW Hausman Test	0.265

Notes: 2SLS. The instrumental variable is the number of senators. The table presents using all control variables. The dependent variable is high-tech exports. All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. *** p<0.01, ** p<0.05, * p<0.1

Table 11 Panel B: IV Approach: First Stage

Dependent Variable: R&D Procurement	
	(1)
the number of senators	0.471***
	(0.131)
Federal Aid to State	0.149
	(0.327)
Graduates in S&E	-1.387**
	(0.582)
Federal R&D expenditure	0.052
	(0.061)
US Population	14.620***
	(2.805)
GDP of state	0.303
	(0.203)
FDI	–0.101
	(0.101)
non RD procurement	–0.077
	(0.136)
University R&D expenditure	1.384***
	(0.264)
Patent	0.185
	(0.118)
Firm R&D expenditure	–0.112
	(0.303)
Observation	402
Kleibergen-Paap F statistic	12.943

Notes: 2SLS. The instrumental variable is the number of senators. The dependent variable is R&D public procurement. All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. *** p<0.01, ** p<0.05, * p<0.1

Table 12 Panel A: IV Approach: Second Stage

Dependent Variable: high-tech exports			
	(1)	(2)	(3)
R&D Procurement	0.154*	0.198*	0.179**
	(0.086)	*(0.116)*	*(0.007)*
Federal R&D expenditure	0.022	0.012	0.003
	(0.027)	*(0.022)*	*(0.002)*
GDP of state	–1.186*		
	(0.698)		
FDI	0.160**	0.011	0.014**
	(0.070)	*(0.018)*	*(0.005)*
University R&D expenditure	0.024	0.052	–0.004
	(0.229)	*(0.215)*	*(0.019)*
patent		–0.006	
		(0.008)	
population		1.599	
		(1.114)	
Company R&D expenditure		0.029	
		(0.055)	
Graduates in Science&Engineering		0.151	
		(0.199)	
Observation	411	359	411
R-squared	0.32	0.074	0.01
DW Hausman Test	0.253	0.217	0.260
year trend	yes	no	no
remove outliers	no	yes	no
exports as share of GDP	no	no	yes

Notes: 2SLS. The instrumental variable is the number of senators. The first column presents replacing year dummies with year trend. The second column presents removing outliers. The third column presents a different measure of the dependent variable (high-tech exports as a share of GDP). All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12 Panel B: IV Approach: First Stage

Dependent Variable: R&D public procurement	(1)	(2)	(3)
the number of senators	0.464***	0.426***	0.482***
	(0.142)	*(0.133)*	*(0.145)*
Federal R&D expenditure	0.007	0.067	0.029
	(0.060)	*(0.064)*	*(0.057)*
GDP of state	–2.784*		
	(1.487)		
FDI	–0.114	0.065**	–0.070
	(0.136)	*(0.030)*	*(0.124)*
University R&D expenditure	0.992***	0.052	1.386***
	(0.313)	*(0.365)*	*(0.319)*
patent		0.027	
		(0.018)	
population		–1.460	
		(1.814)	
Company R&D expenditure		0.029	
		(0.136)	
Graduates in Science&Engineering		–0.535	
		(0.862)	
Observation	411	359	411
Kleibergen-Paap F statistic	10.609	10.199	11.009
year trend	yes	no	no
remove outliers	no	yes	no
exports as share of GDP	no	no	yes

Notes: 2SLS. The instrumental variable is the number of senators. The dependent variable in both columns is R&D public procurement. All regressions control for state and year fixed effects. I cluster the SE (shown in parentheses) at the state level. *** p<0.01, ** p<0.05, * p<0.1