Robust relation between public procurement for innovation and economic development

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Abstract

We found a solid and robust relationship between the share of public procurement for innovation (PPI) in public procurement and GDP per capita for 30 European countries. The share of PPI is highly associated with determinants from "demand pull" as well as "supply push." These findings open new opportunities for the study of the drivers of public procurement for innovation. The study also provides a new methodology for benchmarking.

Keywords: public procurement for innovation, productivity, innovation, cross-country comparisons.
JEL classification: O38, O47, O57.

1. Introduction

Public procurement for innovation (PPI) is increasingly used by governments to stimulate innovation. Under certain circumstances, "demand pull" instruments such as PPI can more effectively promote the development and diffusion of innovations than "supply-push" policies (Borrás & Edquist, 2013). In particular, PPI can be a source for the development of new processes and products (Von Hippel, 2017).

In the context of this paper PPI includes both the procurement of R&D services and the procurement of innovative solutions (Kundu et al., 2020). R&D procurement consists in the acquisition of R&D services aimed at the emergence of solutions (products, services or processes) that do not yet exist. One form of R&D procurement is pre-commercial procurement (PCP), an instrument developed by the European Commission that follows a model in which several suppliers develop innovative solutions in a competitive phased process

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where the results and benefits are shared between the contracting entity and the providers (Apostol, 2017). The public procurement of innovative solutions (PPIS) consists in the acquisition of innovative solution already created by others that are in the market or very close to commercialization. In this case, the public purchaser acts as the first user and acquires a product, service or process that is new to the market or contains substantially new characteristics. The literature recognises the differences between these forms of PPI and of their potential effects on innovation, namely highlighting the fact that R&D procurement in general (and PCP in particular) can act both as a demand-side and a supply-side instrument (Apostol, 2017; Rigby, 2016).

In this context, the European Commission has set ambitious targets for PPI to become 20% of public procurement (3% for R&D procurement and 17% for public procurement of innovative solutions), following typical estimates for pioneer and early demand of innovation (Rogers, 2010) as well as existing targets in other regions and recommendations from start-ups and SMEs behind the Scale-up Europe manifesto (European Commission, 2018)[1]. In practice, the expenditure in PPI of the countries is heterogeneous and much lower than these goals (European Commission, 2021a). We argue that target levels of PPI should rather vary according to the socioeconomic characteristics of each country, given the diversity of situations.

The literature on the determinants of the expenditure in PPI is surprisingly scarce (Kundu et al., 2020). There is a general understanding that PPI process and barriers vary with the level of development of the economy (Li & Georghiou, 2016), the availability of human resources and infrastructures that underpins the innovation capacity (Edler & Georghiou, 2007; Uyarra et al., 2014), and the institutional context enabling good procurement practices (Rolfstam, 2009). In addition, most of the studies are qualitative and/or focused on single cases with limited scope for generalization (Obwegeser & Müller, 2018). For instance, Shin & Lee (2021) find a positive effect of government purchase of innovative products in the productivity of contracted firms in Republic of Korea. Haskel & Wallis (2013) show a relation between the expenditure on public research and the productivity of the economy in the United Kingdom. However, there is a lack of systematic studies which document the extent and nature of the relationship of PPI with these variables.

We perform a cross-country study on the level of expenditures in PPI as a percentage of public procurement by taking into account the socioeconomic context of the countries. The European Commission (2020, 2021b) study is one of the few exceptions (if not the only one) that estimates the PPI for different countries, but it compares the countries in the same basis and against the same goals. We search for patterns of expenditure in PPI according to different levels of development and test the effect of the other factors surveyed in the literature.

We find a strong and robust relationship between the performance of the countries in PPI (as a percentage of public procurement) and the level of devel-

[1] http://scaleupeuropemanifesto.eu

opment (proxied by the GDP per capita). We show that the latter explains the heterogeneity in the levels of PPI by ruling out simultaneity bias. We also quantify the relation between the other factors and PPI. These results contribute to open new perspectives on the study of the drivers of PPI. We also provide a new methodology for benchmarking studies.

2. Data and methodology

We take the most recent estimates for the values and the determinants of the European countries' public procurement for innovation, as well as use standard statistics to document strong associations between the variables.

Data

We use a cross-sectional dataset containing the estimates for the public procurement for innovation (PPI, dependent variable). In our definition, includes public procurement of innovative solution (PPIS) and R&D procurement. Note that it the study of the European Commission (2020, 2021a,b) PPI, PPIS and R&D procurement appear respectively as innovation procurement, public procurement of innovative solutions (there called PPI procurement) and R&D procurement. This report provides estimates for the national expenditures in PPI for 30 countries in Europe (27 EU Member States, United Kingdom, Switzerland and Norway) for the year of 2018. To the best of our knowledge, this is the most recent and comprehensive source of information for international comparison of PPI that is available. To maintain the coherence with the comparisons of the intensity of PPI, we derive the GDP and GDP per capita from the same report.

Data for the countries' Total Factor Productivity (TFP) come from the Penn World Table 10.0 (Feenstra et al., 2015). Expenditures in public and private R&D are from the Eurostat database. Data on the share of employment in services and in highly intensive technology sectors are from the European Innovation Scorecard (Hollanders et al., 2020). Country risk premiums are from Damodaran (2021). European Commission (2019) provides the indexes of both e-Government and of integration of digital technologies in companies. Finally, indicators of good procurement score, including on the integration of the WTO Government Procurement Agreement structure, come from Opentender (2021).

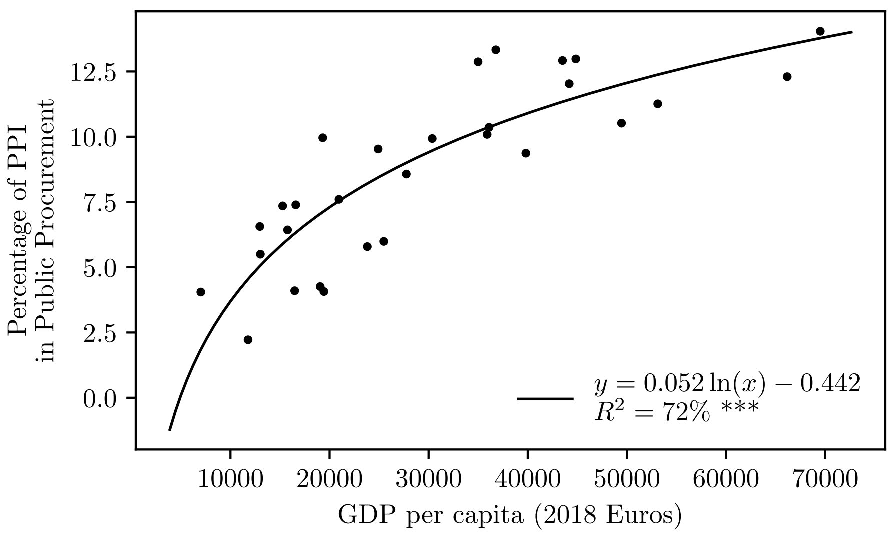
Methodology

To search for strong relations between the estimates of public procurement for innovation and the determinants found in the literature, we employ standard descriptive statistics. We use simple bivariate model fits to observed data, as well as correlations with the explanatory variables. We perform mean comparison tests for assessing the significance of the variables, including ANOVA (analysis of variance). Finally, we test for the endogeneity of key determinants, such as GDP per capita, in explaining changes in PPI through a Hausman specification test.

3. Results

Figure 1 shows the relation between the share of PPI in public procurement (or the intensity of PPI) and GDP per capita (proxy of the level of economic development of the countries). There is a strikingly strong and robust relation between the two variables (R^2 of 72%, significant at more than 99.9%). The relation is nonlinear and follows a logarithmic pattern. The intensity of PPI tends to grow fast in the early stages of development up to 8% around 20,000—25,000€ of GDP per capital, and to evolve more slowly and eventually stabilize afterwards.

Figure 1: Relation between the expenditure in Public Procurement of Innovation (in percentage of public procurement) and GDP per capita



Note: Equation, R^2 and p value denoted by asterisks describe simple bivariate model fits (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). The analysis excludes Ireland and Luxemburg for financial and organizational specificities which affect the comparability of GDP per capita. However, the logarithmic relation remains strong if including these two countries, only the R^2 lowers to 55% ***.

Table 1 presents the Pearson correlation coefficients (including significances) between the variables. Besides GDP per capita, intensity of PPI (PPI/PP) is highly and significantly correlated with "demand pull" factors such as private expenditures of R&D/GDP, e-Government and country risk premium (here negatively correlated). PPI/PP has also high and significant correlations with "supply push" determinants, namely TFP, population with tertiary education among people between 30 and 34 years, and integration of digital technologies in business.

The ANOVA analysis stresses the significance (95% confidence, $p < 0.025$) of ten determinants of the share of PPI in public procurement suggested by the literature: GDP per capita; TFP; share of industrial employment in medium and high technological intensity industry; share of knowledge-intensive services in employment; total expenditures in R&D/GDP; population with tertiary cycle as a percentage of population aged 30 to 34 years; country risk premium; e-Government; integration of digital technologies in business; use of the WTO structure (Table 2). Only the good procurement score is not significant, but this may have to do with the composite nature of this index.

To analyze the heterogeneity within groups, we compare the means of PPI/PP by quartile of each explanatory variable (Figure 2). Similarly to Figure 1, where the intensity of PPI rapidly grows for low values of GDP per capita, we find a resembling pattern for TFP, population with tertiary education and use of the WTO structure. Country risk premium has more effect after the third quartile. Other variables produce strong effects for higher values like in the case of employment in knowledge-intensive services, e-Government and integration of digital technologies in business. A surprising shape appears in the share of R&D expenditures in GDP for which the intensity of PPI increases almost linearly with this "pull" variable. Employment in medium and high technological intensive industry, on the other hand, shows a decrease in the intensity of PPI for the countries in the first quartile. This indicates possible effects of saturation for countries with the highest capacity of the contracted companies, which may find more profitable opportunities of innovation outside the public market.

Finally, Table 3 presents the results of the endogeneity (Hausman) test to the effect of GDP per capita in PPI/PP. The two-stage least squares (2SLS) regressions show a high R^2 (66%) and the F-statistic ($p < 0.01$) rejects the hypothesis of weak instruments, thus validating the instrumentation of GDP per capita. The Sagan test ($p = 0.2909$) does not reject the null hypothesis under which our instruments are valid. Finally, the Wu-Hausman test ($p = 0.2220$) fails to reject the null hypothesis under which GDP per capita is exogenous, thus ruling out simultaneity bias and validating the results of the OLS regression. The results also highlight the hybrid characteristics of PPI, in line with previous research (e.g. Apostol, 2017). Its intensity is found to be related not only to demand side policy but also variables dealing with the supply side capacity.

4. Conclusion

We estimate the effect of several factors on the intensities of PPI of European countries. We find a strong pattern between these intensities and the level of GDP per capita. The relation is nonlinear and increases faster in the early stages of development. Other factors show a high correlation with the intensity of PPI, namely with "supply" (e.g. TFP, share of knowledge-intensive services in employment) and "pull" drivers (e.g. e-Government, total expenditures in R&D/GDP). The striking relationship between PPI and GDP per capita can inspire the development of more studies which integrate this feature.

The striking relationship between the intensity of PPI and GDP per capita suggests that the room for improvements in PPI are bounded by the socio-economic context of each country. Structural factors, such as the lack of PPI (and other) competences in the public administration, or the share of high-tech sectors in the private economy, may hinder the growth of PPI in the short run. However, for some countries, the PPI intensity is much lower than what could be expected given their level of GDP per capita (as measured by their vertical distance to the trend line in 1). This can be seen as a benchmark, leading governments to target institutional improvements—such as changes in public procurement laws and regulations, the creation of public funds for financing PPI projects, specialized training of public managers, among others—that contribute to increase the country's PPI intensity in the short run. Further research on PPI will hopefully improve our knowledge on both short run and more structural features that foster or hinder the use of public procurement to promote innovation in each national context. Future work should also shed more light on the differentiated effects of R&D procurement and PCP, namely in terms of reinforcing the innovation system's capabilities and of the emergence of innovative solutions to address current societal challenges.

Table 1: Correlation matrix

	PPI/PP	GDPpc, €	TFP	Share of the knowledge--intensive services in employment	Total expenditures in R&D/GDP, %	Private expenditures in R&D/GDP, %	Population with 3rd cycle, % of population aged 30 to 34 years	Country risk premium, %	e--Government, score	Integration of digital technologies (Business), score	Good procurement score	Use of the WTO structure
PPI/PP	–											
GDPpc, €	.587**	–										
TFP	.636**	.780**	–									
Share of the knowledge--intensive services in employment	.499**	.851**	.579**	–								
Total expenditures in R&D/GDP, %	.641**	0.355	.411*	.360*	–							
Private expenditures in R&D/GDP, %	.606**	0.342	.416*	.363*	.983**	–						
Population with 3rd cycle, % of population aged 30 to 34 years	.513**	.565**	.409*	.481**	0.218	0.173	–					
Country risk premium, %	-.609**	-.601**	-.668**	-.528**	-.628**	-.611**	-.376*	–				
e-Government, score	.663**	.371*	0.357	0.236	.418*	0.327	.512**	-.555**	–			
Integration of digital technologies (Business), score	.676**	.572**	.468**	.396*	.530**	.493**	.551**	-.520**	.711**	–		
Good procurement score	0.185	0.343	0.179	0.188	0.105	0.15	0.227	-0.195	0.175	0.357	–	
Use of the WTO structure	.566**	.357*	0.265	.383*	.525**	.488**	0.291	-.439*	0.295	.397*	0.078	–

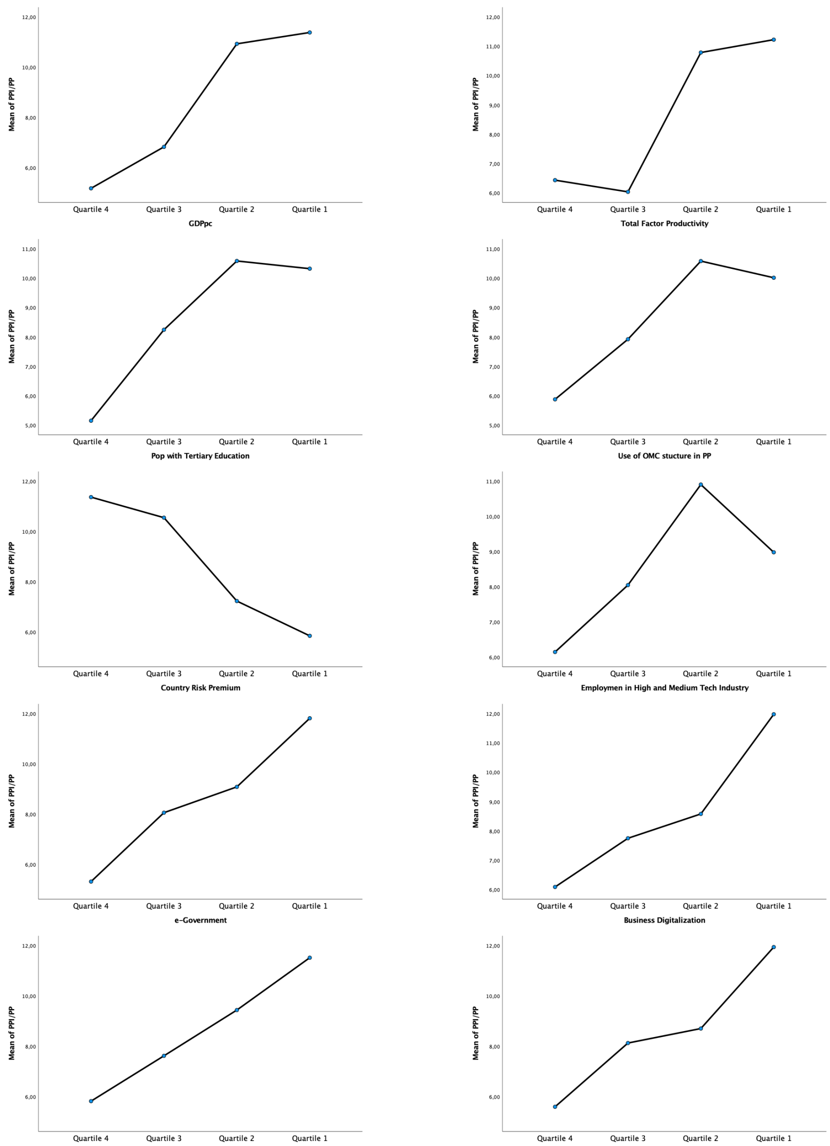
Note: ** Correlation is significant at the 0.01 level (2 sides). * Correlation is significant at the 0.05 level (2 sides).

Table 2: ANOVA analysis for PPI/PP across countries (one-factor, one tale)

		Sum of Squares	Degrees of Freedom	Mean Square	F	Sig.
GDP per capita, €	Between groups	212.6	3	70.9	18.4	.000
	Within groups	193.7	27	3.8		
	Total	316.3	30			
Total Factor Productivity	Between groups	179.1	3	59.7	11.749	.000
	Within groups	137.2	27	5.1		
	Total	316.3	30			
Share of knowledge-intensive services in employment, %	Between groups	154.3	3	51.4	8.573	.000
	Within groups	162.0	27	6.0		
	Total	316.3	30			
e-Government	Between groups	152.4	3	50.8	8.784	.000
	Within groups	150.4	26	5.8		
	Total	302.8	29			
Country risk premium, %	Between groups	150.4	3	50.1	7.935	.001
	Within groups	164.3	26	6.3		
	Total	314.7	29			
Population with 3rd cycle, % of population aged 30 to 34 years	Between groups	139.8	3	46.6	7.126	.001
	Within groups	176.6	27	6.5		
	Total	316.3	30			
Total expenditures in R&D/GDP, %	Between groups	135.5	3	45.2	6.746	.002
	Within groups	180.8	27	6.7		
	Total	316.3	30			
Integration of digital technologies (Business)	Between groups	130.2	3	43.4	6.536	.002
	Within groups	172.6	26	6.6		
	Total	302.9	29			
Use of the WTO structure	Between groups	103.1	3	34.4	4.352	.013
	Within groups	213.2	27	7.9		
	Total	36.3	30			
Share of industrial employment in medium and high technological intensity industry, %	Between groups	93.3	3	31.1	3.763	.022
	Within groups	223.1	27	8.3		
	Total	316.3	30			
Good procurement score	Between groups	54.3	3	18.1	1.866	.159
	Within groups	262.0	27	9.7		
	Total	316.3	30			

Note: sorted in decreasing order by mean square between groups. Metrics in index, unless otherwise specified

Figure 2: ANOVA plots for shares of PPI on public procurement by quartiles of the surveyed variables



Note: higher quartile is higher value, even when this is a bad result (e.g. country risk premium). Only variables with significant mean differences are shown.

Table 3: OLS, 2SLS and endogeneity test

	OLS	2SLS
Variables		
GDPpc	0.0000465*	0.0000573**
	(0.000187)	(0.0000193)
R&D	1.398371**	1.351192**
	(0.4885967)	(0.4591977)
E-government	0.1048463**	0.0990973**
	(0.03464)	(0.0327472)
Intercept	-1.505159	-1.444221
	(1.830009)	(1.715317)
First Stage Instruments		
Total Factor Productivity		66635.9**
		(13888.26)
Employment in knowledge intensive services		1930.442**
		(290.3118)
Model Fit		
R2	0.6627	0.6583
N	30	30
2SLS Diagnosis		
Wu-Hausman test - F(1,25)		1.56871; $p = 0.2220$
Sargan test - $\text{Chi}^2(1)$		1.11533; $p = 0.2909$
Weak Instruments test - F(2,25)		56.7001; $p < 0.01$

The estimated equation is: $\text{PPI/PP}_i = \alpha + \beta\text{GDP per capita}_i + \gamma' X_i + \varepsilon_i$. The dependent variable in the first-stage is GDP per capita (GDPpc). In the first stage, GDPpc is instrumented by the total factor productivity (TFP) and the share of employment in knowledge intensive services of the countries. In the second stage, the dependent variable is the share of Public Purchase for Innovation (PPI) in Public Purchase (PP), i.e. PPI/PP. This is regressed on the predicted values of GDPpc from the first-stage as well as other countries' characteristics (X_i) known to affect the PPI/PP: share of total R&D expenditures in GDP (R&D) and E-Government. For comparison, the second stage is also regressed using the OLS estimation method. The Cragg-Donald F-statistic is the first-stage F-test for weak instruments. The Sargan chi-squared is the test of overidentifying restrictions. The Wu-Hausman F-statistic is the test for endogeneity. Section 2 provides more details about the variable definitions and data sources. ε_i is an error term. Standard errors are in parentheses. $^{**}p < 0.01$, $^{*}p < 0.05$.

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References

Apostol, R. (2017). *Trials and tribulations in the implementation of pre-commercial procurement in Europe*. Springer.

Borrás, S., & Edquist, C. (2013). The choice of innovation policy instruments. *Technological Forecasting and Social Change*, *80*, 1513–1522.

Damodaran, A. (2021). Country default spreads and risk premiums. https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html, last accessed on 26/08/21.

Edler, J., & Georghiou, L. (2007). Public procurement and innovation—resurrecting the demand side. *Research Policy*, *36*, 949–963.

European Commission (2018). Commission notice — guidance on innovation procurement, c(2018)3051.

European Commission (2019). *Digital Economy and Society Index (DESI) 2019*. https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2019, last accessed on 26/08/21.

European Commission (2020). Benchmarking of r&d procurement and innovation procurement investments in countries across europe. DG GNECT, F – Digital Single Market, F3 – Digital innovation and Blockchain, October 10, https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=69920, last accessed on 2/08/21.

European Commission (2021a). Commission notice — guidance on innovation procurement, brussels, 18.6.2021, c(2021) 4320 final. https://ec.europa.eu/docsroom/documents/45975, last accessed on 02/08/21.

European Commission (2021b). The strategic use of public procurement for innovation in the digital economy smart 2016/0040 - final report. Directorate-general for Communication, Networks, Content and Technology, Directorate F – Digital Single Market, Unit F3 – Digital innovation and Blockchain, https://data.europa.eu/doi/10.2759/936544, last accessed on 2/08/21.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*, 3150–82.

Haskel, J., & Wallis, G. (2013). Public support for innovation, intangible investment and productivity growth in the UK market sector. *Economics Letters*, *119*, 195–198.

Hollanders, H., Es-Sadki, N., Merkelbach, I., & Khalilova, A. (2020). European Innovation Scoreboard 2020. Report of the European Innovation Scoreboard project, Brussels: European Commission, 23 June 2020.

Kundu, O., James, A. D., & Rigby, J. (2020). Public procurement and innovation: a systematic literature review. *Science and Public Policy*, *47*, 490–502.

Li, Y., & Georghiou, L. (2016). Signaling and accrediting new technology: Use of procurement for innovation in China. *Science and Public Policy*, *43*, 338–351.

Obwegeser, N., & Müller, S. D. (2018). Innovation and public procurement: Terminology, concepts, and applications. *Technovation*, *74*, 1–17.

Opentender (2021). Opentender portals - making public tenders more transparent. DIGIWHIST project, https://opentender.eu/, last accessed on 02/08/2021.

Rigby, J. (2016). The impact of pre-commercial procurement on innovation. In *Handbook of Innovation Policy Impact*. Edward Elgar Publishing.

Rogers, E. M. (2010). *Diffusion of Innovations*. Simon and Schuster.

Rolfstam, M. (2009). Public procurement as an innovation policy tool: the role of institutions. *Science and Public Policy*, *36*, 349–360.

Shin, K., & Lee, J.-D. (2021). Impact of public procurement for innovation on firm productivity. *Applied Economics Letters*, (pp. 1–6).

Uyarra, E., Edler, J., Garcia-Estevez, J., Georghiou, L., & Yeow, J. (2014). Barriers to innovation through public procurement: A supplier perspective. *Technovation*, *34*, 631–645.

Von Hippel, E. (2017). *Free Innovation*. The MIT Press, Cambridge: MA.