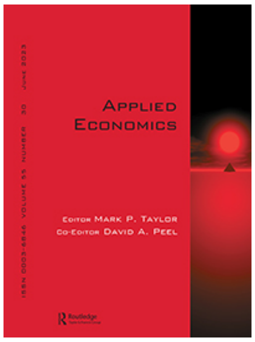

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Productivity and regulation in the construction sector: evidence for OECD countries

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ABSTRACT
Labour productivity growth in the construction sector has been very weak in recent decades in most OECD countries. This paper addresses this issue based on a panel of 23 countries over the period 1995–2015. First, we use the Ackerberg, Caves, and Frazer (2015) method to propose a multifactor explanation for this lack of productivity growth: (i) average TFP growth is close to zero and even negative for most countries; (ii) average contributions to growth of capital and intermediate inputs are positive but weak, respectively of 0.05% and 0.90% per year, and much smaller than in the manufacturing sector over the same period (respectively of 0.40% and 3.10% per year). Then, we investigate whether reforms of regulations specific to the construction sector might boost productivity there. Using regulation indicators from the 'Doing Business Report', we find a negative impact of these regulations on TFP, but not on the intensities of capital and intermediate inputs. Our results suggest that reducing the construction sector regulations might bolster productivity: a switch to the lightest regulations would lead to a long-term TFP increase of 6% on average.

KEYWORDS
Construction sector; production function; labour productivity; total factor productivity; regulation and business law

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I. Introduction

The Construction Sector (CS) is an essential component of every OECD economy. It is responsible for building new houses, apartments, factories, offices and schools, roads, bridges, ports, railroads, sewers, and tunnels. In OECD countries, the construction industry represents on average 6.47% of GDP (OECD 2008) and has an impact on the whole economy by providing the buildings and infrastructure on which virtually all other sectors depend.

Unfortunately, in recent decades, the sector's labour productivity growth has been very weak in most OECD member countries, with even downward trends in many of them (see for instance Xerfi 2019, for European countries). This paper addresses this issue. Our first main original contribution is to measure the CS Total Factor Productivity (TFP) and provide a detailed analysis of factors' contributions to the sector's growth, whereas the literature focuses on Labour Productivity (LP) only. Then, the second main original contribution of this paper is to investigate whether reforms of sector-specific regulations might boost its labour productivity through their effects on the factors of growth, i.e. TFP, capital intensity, and intermediate input intensity. This is particularly relevant as the CS is highly regulated.

To our knowledge, the previous literature on CS productivity focused exclusively on labour productivity. Xerfi (2019) shows that average labour productivity in the CS declined between 1995 and 2018 in five European countries (France, Germany, Italy, Spain, and the UK) and that the average yearly growth in the labour productivity gap between the construction and manufacturing sectors exceeded −1.9 points for each country. Other analyses of labour productivity trends in the CS – most of them published in engineering journals – focus on specific countries (Allmon et al. 2000 for the U.S.A; Crawford and Vogl 2006 for the UK; Xue et al. 2008 for China; Richardson 2014 for Australia;), and show consistent patterns.

Our paper completes this literature using a TFP measure to investigate the lack of growth in the CS on an unbalanced panel of 23 OECD countries from 1995 to 2015. One contribution of our paper is to argue that the Ackerberg, Caves, and Frazer

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(2015) method, (hereafter ACF) is the best suited method for estimating the production function in the CS so as to measure TFP and for providing a detailed analysis of changes in the sector. In order to emphasize the distinctive features of the CS, we make a systematic comparison with the Manufacturing Sector (MS).[1]

Then, we investigate how to increase CS productivity. There is already a body of literature investigating various drivers of CS productivity with firm level data for specific countries, such as management skills and manpower issues in the U.S.A (Rojas and Aramvareekul 2003); equipment technology in the U.S.A (Goodrum and Haas 2004); crew size, job type, and construction method in Montreal (Moselhi and Khan 2010); the digital approach approximated by building information modelling in Malaysia (Wong, Rashidi, and Arashpour 2020). At the same time, the relationship between regulation and productivity has been the subject of numerous empirical studies (Dufour, Lanoie, and Patry 1998; Nicoletti and Scarpetta 2003; Conway et al. 2006; Crafts 2006; Barone and Cingano 2011). According to this literature, anticompetitive regulations reduce incentives to invest in research and development activities (Bourlès et al. 2013; Ciriaci, Moncada-Paternò-Castello, and Voigt 2016) and more generally to improve their productivity. However, although it is widespread, such a study is absent from a highly regulated sector like the CS with a lack competition as raised by Lowe's (1987), Budiwibowo et al. (2009) and Kroft et al. (2020) in Great-Britain, Indonesia and the US respectively.

Our paper fills this gap, using the CS 'Doing Business project' regulatory indicators on a subsample of 20 countries for the period 2006–2015. These indicators track the procedures, time, and cost of building a warehouse. Comparison with the MS enables us to implement a placebo test: if our measures of CS-specific regulations are exogenous, we should find they make no significant impact on the MS TFP.

Using our panel of 23 OECD countries, we confirm the lack of labour productivity growth already observed for some countries in the different papers already mentioned. The labour productivity growth in the CS of 0.4% per year on average over the period 1995–2015 contrasts with the average 3.6% annual growth in the MS, even though capital intensity grew significantly in both sectors (2.0% in the CS against 3.6% in the MS). This lack of growth is linked to the negative yearly TFP growth of −0.1% on average, with TFP growth being even negative on average for 16 countries. However, TFP is not the main factor explaining the difference with the MS, as the TFP growth in the MS sector is also weak, with an average yearly growth of 0.15%. On the contrary, all the intermediate input, labour and capital contributions to the CS growth are much lower than in the MS. This difference is particularly marked for capital contribution, which is on average of only 0.05% per year in the CS and of 0.40% per year in the MS. This is explained notably by the much smaller capital elasticity in the CS, as underlined by the ACF estimates (0.03 against 0.11). However, this difference may be linked to the practice in this sector of renting costly plant and equipment. In other words, we should be cautious when dealing with the break down between capital and intermediate inputs in the CS. Taken together, the capital and intermediate input contribution to growth comes to 0.95% per year for the CS and 3.50% in the MS, so there is still a huge difference between the two sectors.

According to our estimation results, the CS-specific regulations have a negative impact on the sector's labour productivity and TFP, but not on capital and intermediate input intensities. This effect is robust to the use of numerous control variables, notably indicators for regulations not specific to the CS. Moreover, we find no impact of the CS regulations on MS labour productivity or TFP. Based on these results, we show that a switch of all countries to the lightest practices in terms of CS-specific regulations may increase the average TFP by 6.2%. By way of comparison, this increase would more than make up for the lack of TFP growth over the period 1995–2015 compared with the MS (the aggregate difference of TFP growth between the two sectors over the whole period is of 5.0%). However, this result should be interpreted

[1]For convenience, this paper introduces five acronyms: LP and TFP for Labor and Total Factor Productivity; CS and MS for Construction and Manufacturing Sectors; ACF for Ackerberg, Caves, and Frazer (2015).

as the long-run TFP gains of reforms that may be very ambitious in some countries. Moreover, it would not be enough to offset the low contributions of capital and intermediate input intensities in the CS.

The paper is organized as follows. The second section describes our data. Section III shows the TFP analysis, from the TFP equation and estimation method to the analysis of the TFP changes. The fourth section investigates the regulatory impact and provides a simulation of the potential effects of CS regulation reforms. We conclude in the fifth section.

II. Data

Production function data

Our main source of gross output and production-factor data is the OECD STAN database. The STAN database is a comprehensive tool for analysing industrial performance in countries at a relatively detailed level of activity. It includes comparable annual measures of output, value added and its components, labour force, investment, and capital stock, starting in 1970. Our sample concerns two sectors of activity: construction and manufacturing. The construction sector in the STAN database includes the ISIC rev. 4 codes from 41 to 43. These are building construction and real estate promotion (41), civil engineering (42), and specialized construction works (43). The manufacturing sector includes sub-sectors with ISIS rev. 4 codes ranging from 10 to 33. We compare the CS to the MS in order to emphasize the distinctive characteristics of the CS. We use the MS for comparison as productivity in this sector is much better measured than in the business and public service sectors.

Our measure of the labour input variable is the number of persons employed (thousands) only. Gross output, investment, and intermediate inputs are measured in constant 2005 prices. In order to compare these values across countries and compute the TFP, we focus on the labour productivity and production factor intensities (i.e. capital stock and intermediate inputs are divided by the number of persons employed) and we convert these values using OECD aggregate GDP US$ 2005 PPPs. Our stock of productive capital is computed from investment using the unified perpetual inventory method proposed by Berlemann and Wesselhöft (2014) but adopting a constant capital depreciation rate (Online Appendix A provides further details of our capital stock calculation). Finally, for both the construction and the manufacturing sectors, we have assembled an unbalanced panel of 23 OECD countries from 1970 to 2016. However, values are missing for many countries before 1995, so when comparing country changes, we prefer to focus on the period 1995–2015 (data availability for each country is presented in Online Appendix B).

Figure 1 shows the average yearly growth in labour productivity and capital intensity between 1995 and 2015 for the construction and manufacturing sectors. The dynamics of labour productivity in these sectors are very different. On average, labour productivity in the CS is fairly flat (the average yearly growth is 0.4%), whereas it increases by 3.6% per year in the MS. This comparative absence of labour productivity growth in the CS is observed in most countries: (i) labour productivity growth is lower in the CS than in the MS for all countries except Latvia; and (ii) the average growth in the CS is even negative for 10 countries, which is never the case in the MS. By contrast, capital intensity grew by 2.0% per year on average in the CS over the period. This growth is slower than the 3.6% in the MS, but significant and it underlines the need to investigate the structural weaknesses of CS productivity growth.

Online Appendix B, Figures B1 and B2, supplement our descriptive analysis. They show that the intermediate input intensity grew in both sectors but faster in the MS (1.1% in the CS against 3.5% in the MS) and they reveal a marked difference in employment dynamics between the two sectors: whereas the number of workers fell by 0.88% per year on average in the MS, it increased by 0.68% in the CS. They also underline the characteristics of the CS: (i) the CS is highly labour intensive compared to the MS, with an average capital intensity in the CS of only 30% of the capital intensity in the MS (this pattern is observed in almost all countries); (ii) the intermediate input intensity is also lower in the CS, with an average intensity of 55% of

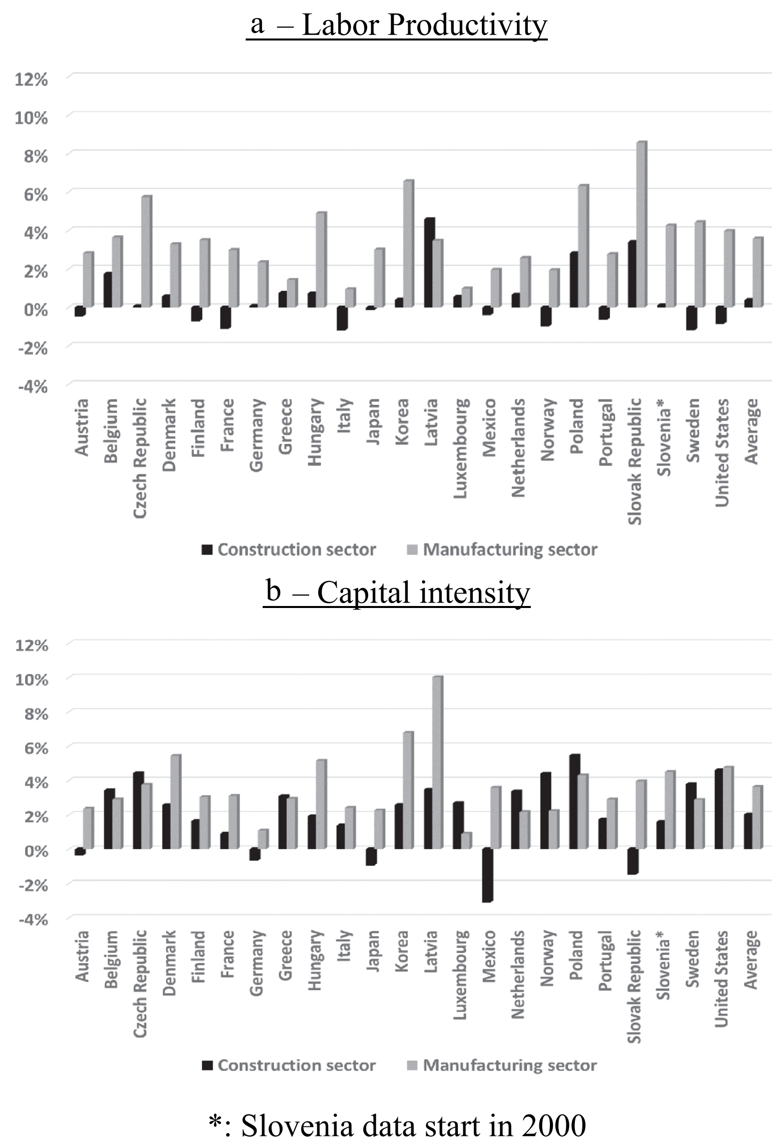

Figure 1. Average yearly growth in labor productivity and capital intensity, 1995–2015 .

the intensity in the MS. These results emphasize the need to take account of intermediate inputs, potential returns to scale, and CS-specific parameters when investigating TFP.[2]

Regulatory indicators

In a broad sense, regulation can be defined as a set of indications, laws, prescriptions, rules, and other legal texts governing corporate activity. It can address public interest concerns about market failures, monopoly conditions, externalities, and the problem of asymmetric information. In this context, regulation can promote competition in certain industries by ensuring that market power in natural monopoly segments is not abused and by providing incentives for market actors. However, regulatory frameworks do not always do this. First, some regulations may deviate from their original public interest objectives, resulting in the

[2]With the aim of estimating the TFP, it is also interesting to observe the correlation between labour productivity and production factor intensities. For both the CS and MS, the level of labour productivity in 2005 is strongly correlated to capital intensity (their correlation coefficients are 0.63 and 0.72, respectively) and to intermediate input intensity (0.47 and 0.77, respectively). This is also the case for the correlation between the average growth in labour productivity and intermediate input intensities (0.60 for CS and 0.79 for MS). However, the correlation between the country average growth in labour productivity and capital intensity, which is of 0.44 for the MS, is not significant for the CS (with a value of 0.12). This last point may be linked to the low capital intensity of the CS and to the practice of renting costly plant and equipment in this sector.

protection of special interest groups. Furthermore, regulations (and their implementation) sometimes entail costs that exceed their expected benefits, leading to what is known as 'institutional failure'. Then again, changes in demand and regulatory technical progress may make regulatory design obsolete. As a result, inappropriate regulation can adversely affect the productivity of an economy.

To test the effect of regulations on labour productivity and TFP in the construction sector, we use the regulatory indicators provided by the 'Doing Business project' through the 'Dealing with Construction Permits' topic. This topic tracks the procedures, time, and cost of building a warehouse, including the necessary licences and permits, all required notifications, inspections, and utility connections.[3] Information is collected from experts in construction licencing, including architects, civil engineers, construction lawyers, construction firms, utility service providers, and public officials who deal with building regulations, including approvals, permit issuance, and inspections.[4] It provides three indicators:

- The number of procedures: A procedure is any interaction of the construction company's employees, managers, or any party acting on behalf of the company, with external parties, including government agencies, notaries, the land registry, public utility companies, and the public inspector, hiring private inspectors and technical experts when necessary.
- The total duration of all procedures: This measure captures the median time, recorded in days, that local experts believe is required to complete a procedure in practice. The minimum time required for each procedure is assumed to be one day, except for procedures that can be performed entirely online, for which the required time is recorded as half a day.
- The total cost of all procedures: This cost is recorded as a percentage of the warehouse value (assumed to be 50 times income per capita). Only official costs are recorded. All fees associated with completing the procedures to legally build a warehouse are recorded, including those associated with obtaining land-use approvals and preconstruction design clearances; receiving inspections before, during, and after construction; obtaining utility connections; and registering the warehouse with the property registry.

These indicators are available for a subsample of our productivity database covering 20 countries for the period 2006–2015. Figure 2 shows their first and last values for all countries. There are important differences between countries and these differences are persistent. Their persistence is a characteristic of these indicators, but there are some changes that can be used to identify the impact of these regulations on productivity. The number of procedures has changed for 12 of our 20 countries, the total duration of all procedures for 15 countries and the total cost of all procedures have changed for all countries except the Slovak Republic, with a marked increase or decrease in many countries.

These indicators are used as proxies for the set of regulations implemented in the CS. Therefore, the estimated impact of an indicator should not be attributed entirely to these specific regulations as part of the impact may come from other unobserved CS regulations correlated with them. Moreover, CS regulations may be correlated with other country regulations. In order to prevent this potential omission bias, we include in the main estimated equations the OECD Energy, Transport and Communication Regulation (ETCR) indicator and 'Size of Government' and 'Freedom to trade internationally' indicators from the Fraser Institute's Economic Freedom Index.[5] The ETCR indicator is designed to measure the extent to which competition and firms' choices are restricted in these sectors when there is no a priori reason for government interference, or when regulatory goals could plausibly be achieved by less coercive means.

[3]We do not include environmental indicators such as building safety and quality due to data availability issues.
[4]To make the data comparable across economies, several assumptions are made about the business, the warehouse project, and the utility connections. See World Bank Group, Doing Business project (http://www.doingbusiness.org/) for more information on these indicators.
[5]Estimated impact of other Fraser Institute regulation indicators are not statistically significant and so not included in the main estimated equation. Estimation results of specifications including these indicators are presented in Online Appendix E.

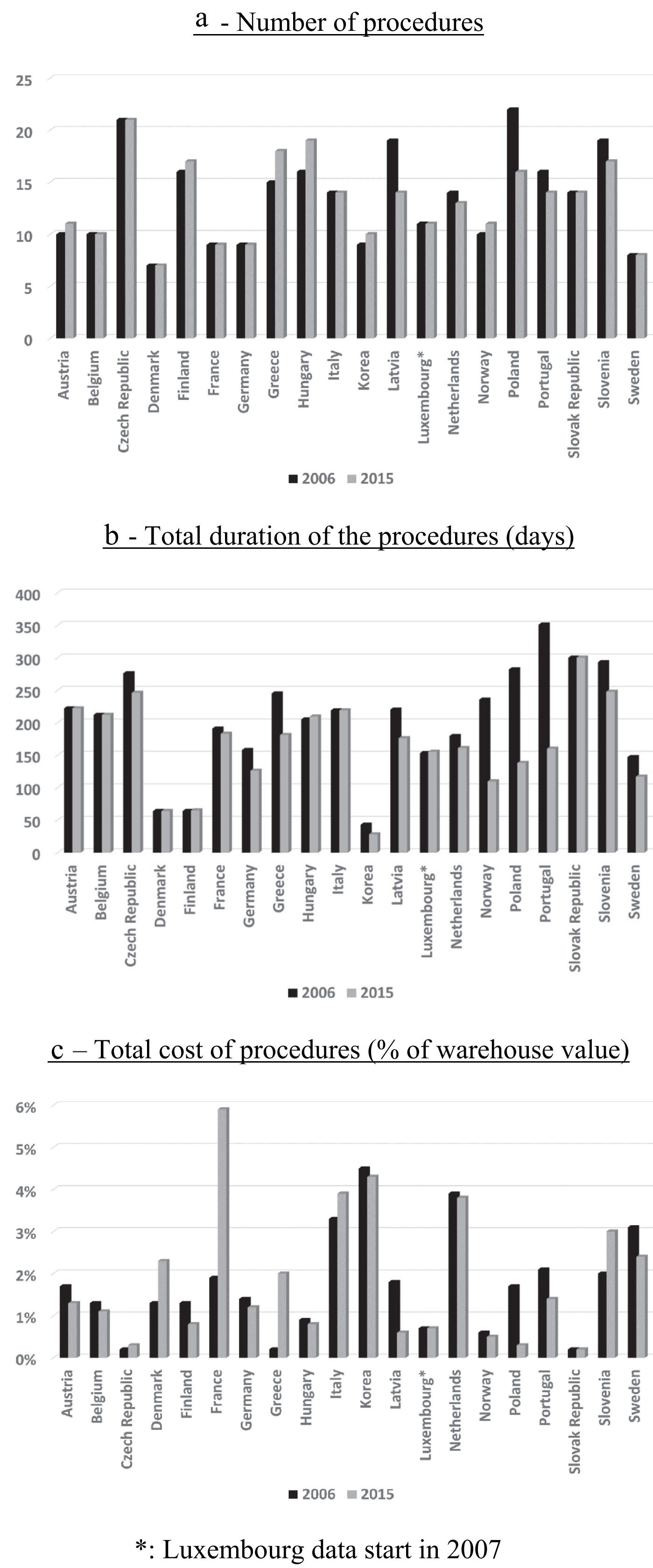

Figure 2. CS "Doing business project" indicators.

These regulations are specific to other sectors than the CS, but they may have an impact on the latter because the CS uses intermediate inputs produced by them. This indicator is placed on a scale from 0 to 6, with 0 for the most pro-competition regulations. The 'Freedom to trade internationally' indicator makes allowance for taxes, regulatory trade barriers, the black-market exchange rate and controls on the movement of capital and people. The 'Size of Government' indicator covers government consumption, transfers and subsidies, government enterprises and investment, top marginal tax rate, and state ownership of assets. The indicators from the Fraser Institute are placed on a scale from 0 (Least Freedom) to 10 (Most Freedom), so this indicator is to be read in the reverse direction to the OECD indicators.

III. TFP analysis

TFP equation

We assume a Cobb-Douglas production function written as follows:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} M_{it}^{\beta_m}$$

Where Y_{it} represents gross output of country i in period t, K_{it}, L_{it}, and M_{it} are inputs of physical capital, labour (number of persons employed), and materials (intermediate inputs), respectively, and A_{it} is the Hicksian neutral efficiency level. Taking the natural logarithm of this production function:

$$ln(Y_{it}) = \beta_0 + \beta_k ln(K_{it}) + \beta_l ln(L_{it}) + \beta_m ln(M_{it}) + \omega_{it} + \varepsilon_{it}$$

where $\beta_0 + \omega_{it} + \varepsilon_{it} = \ln(A_{it})$. β_0 measures the mean efficiency level across countries and over time. The term ε_{it} (the error term) is not observable by the firm prior to the input decision in period t. In contrast, ω_{it} represents the productivity level that is observed or predictable by the firm when it makes the input decisions.

We rewrite this equation to get the estimated equation:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_m m_{it} + \gamma l_{it} + \omega_{it} + \varepsilon_{it} \quad (1)$$

where the logarithm of the gross output per worker $y_{it} = ln(Y_{it}/L_{it})$ depends on the logarithm of the capital and intermediate input intensities, $k_{it} = ln(K_{it}/L_{it})$ and $m_{it} = ln(M_{it}/L_{it})$, as well as of labour, $l_{it} = ln(L_{it})$, with $\gamma = (\beta_l + \beta_k + \beta_m - 1)$ measuring the return to scale.

Finally, TFP can be assessed as follows:

$$\ln(\widehat{TFP}_{it}) = y_{it} - \left(\hat{\beta}_k k_{it} + \hat{\beta}_m m_{it} + \hat{\gamma} l_{it}\right) \quad (2)$$

TFP estimation method

Review of the main TFP estimation method

There are several methods for assessing TFP. They range from parametric methods (e.g. fixed effects; instrumental variables; generalized method of moments of Blundell and Bond 1998) to semi-parametric or stochastic methods (e.g. Olley and Pakes 1996; Levinsohn and Petrin 2003; Ackerberg, Caves, and Frazer 2015) to non-parametric methods (e.g. elasticity calibration; data development analysis developed by Banker, Charnes, and Cooper 1984). Each method has its advantages and drawbacks. Thus, the choice of the method must be made depending on the research question.[6] In this section we motivate our choice of the Ackerberg, Caves, and Frazer (2015) method (we present estimation results using alternative methods in online Appendix C).

Assuming strict (or within individual) exogeneity of the regressors, the OLS (or fixed effects) estimator provides unbiased coefficients. However, because this exogeneity assumption is invalid, these estimators typically provide a very small capital coefficient (Van Beveren 2012). Unlike the OLS estimator, the instrumental variables (IV) estimator method does not rely on strict exogeneity. Nevertheless, this method requires several conditions, notably concerning the variable(s) used as external instruments, and such 'good' instruments are particularly difficult to find. To remedy this, Blundell and Bond (1998) propose a GMM estimator using lagged first difference as instruments. However, this estimator requires

[6] Kané (2022) proposes a sensitivity analysis of the choice of these estimation methods using firm-level data. The author shows that the ACF method can be considered a good estimator of TFP in the French construction sector.

a longer time series, and the explanatory power or exogeneity of such instruments may be strong assumptions.

In this paper, we use the semi-parametric approach first proposed by Olley and Pakes (1996) and later adjusted by Levinsohn and Petrin (2003). The general idea of this semi-parametric approach is that, under certain statistical and theoretical assumptions, optimal input decisions can be inverted to essentially allow an econometrician to 'observe' unobserved productivity shocks. While the Olley and Pakes method resolves the simultaneity bias between production factors and unobserved productivity shocks using the investments as a proxy (the strict monotonicity assumption), the Levinsohn and Petrin method uses intermediate inputs to control for the unobserved productivity shock.

Using intermediate inputs as a proxy for the unobserved productivity shock rather than the investment stock has some advantages. It makes it easier to verify the monotonicity condition (i.e. that intermediate inputs are a strictly increasing function of unobserved productivity). Investment data can be lumpy; for example, for firm-level data, we often see zero investment. Therefore, this casts doubt on the monotonicity condition, at least for observations where investment is zero. Another major advantage of using the Levinsohn and Petrin method relates to the criticism of Griliches and Mairesse (1998). In the Olley and Pakes method, the assumption about firms' investment decisions excludes any unobservable firm-specific variable (other than the productivity shock) affecting investment demand. This, for example, excludes unobserved capital adjustment costs that vary across firms, as well as unobserved firm-specific shocks to investment prices. Finally, the use of intermediate goods as a proxy for unobserved productivity is particularly important for the construction industry, where expenditure on equipment and plant rentals is very high. Moreover, no amount of labour can replace the concrete, asphalt, wood, and other materials required for building.

Ackerberg, Caves, and Frazer (2015) argue that even if the monotonicity assumptions are valid, the Olley and Pakes and the Levinsohn and Petrin methods involve identification problems. Specifically, the authors argue that the Olley and Pakes and the Levinsohn and Petrin procedures correctly identify the labour coefficient only under specific conditions:

(1) i.i.d. optimization error in labour (e.g. there is an optimal level of labour input, but, for some reason, the firm chooses that optimal level plus **exogenous** noise to the desired input level);
(2) i.i.d. shocks to the price of labour or output after the choice of intermediate inputs (or investment) but before the choice of labour;
(3) in the Olley and Pakes context, labour is non-dynamic (i.e. a firm's choice of labour for period t has no impact on the next periods) and chosen at $t - b$ as a function of productivity (in t-b) while investment is chosen at t.

This identification problem is considered by the Ackerberg, Caves, and Frazer (ACF) method. To overcome this issue, the authors consider the labour input as an argument of the unobserved productivity function. More precisely, the model allows for the existence of exogenous, serially correlated, unobserved, firm-specific shocks to the price of labour, or unobserved, firm-specific adjustment costs to labour input. It also allows the labour input to have dynamic effects (e.g. hiring or firing costs) in a more general way. Thus, ACF start from the same point of view as the Levinsohn and Petrin method by taking the same proxy function but including labour input:$m_{it} = f_t(k_{it}, l_{it}, \omega_{it})$. One interpretation of this assumption is that the gross output production function is a Leontief production function in the intermediate inputs (i.e. the intermediate inputs are proportional to output, e.g. see Gandhi, Navarro, and Rivers 2011).

Wooldridge (2009) proposes an alternative implementation of the Olley and Pakes/Levinsohn and Petrin moments that involves simultaneously minimizing the first and second stage moments. Using the Levinsohn and Petrin model, he suggests estimating all the parameters simultaneously using the moment conditions. This method has the advantage of dealing with the problem of functional dependence (problem of identifying the labour input) and of providing simpler standard error calculations; however, it is more time-consuming and probably more error-prone than two-step approach such as ACF method.[7] Because TFP is already difficult to measure in the CS due to its fragmented structure, any formal measurement error should be avoided.

Of course, there are non-parametric methods that have the advantage of not imposing a functional form on the production function. However, they involve assumptions that are difficult to accept in the CS, particularly the assumption of a perfect market for the calibration of elasticities and the deterministic model for the DEA method.

To conclude, the ACF model seems better suited to the hard facts of the CS. Indeed, while correcting the Olley and Pakes and Levinsohn and Petrin methods, this method emphasizes the importance of intermediate inputs that are crucial for the sector. Moreover, unlike Wooldridge's (2009) method, the ACF method is less prone to measurement error. Accordingly, to obtain the different elasticities, we estimate equation (1) using the ACF method.

The Ackerberg, Caves, and Frazer (ACF) method

The endogeneity issue when estimating the production function is that firms' decisions depend on their productivity. Given the strict monotonicity assumption, we can invert intermediate input demand in order to replace the firm's productivity level in equation (1):

$$y_{it} = \beta_0 + \beta_k k_{it} + \gamma l_{it} + \beta_m m_{it} + f_t^{-1}(k_{it}, l_{it}, m_{it}) + \varepsilon_{it}$$

where $\omega_{it} = f_t^{-1}(k_{it}, l_{it}, m_{it})$ is the productivity level

We note further $\Phi_t(k_{it}, l_{it}, m_{it}) = \beta_0 + \beta_k k_{it} + \gamma l_{it} + \beta_m m_{it} + f_t^{-1}(k_{it}, l_{it}, m_{it})$ to alleviate the equations.

Using the first stage moment condition, we have:

$$E[\varepsilon_{it}|I_{it}] = E[y_{it} - \Phi_t(k_{it}, l_{it}, m_{it})|I_{it}] = 0$$

where I_{it} represents a set of information. We note that, unlike in the Olley and Pakes and Levinsohn and Petrin methods, no coefficient is identified in the first step. However, the first step will always be important for 'eliminating' the untransmitted error from the production function. In short, all the coefficients are estimated in the second step using the following second stage moment condition:

$$E[\xi_{it} + \varepsilon_{it}|I_{it-1}] = E[y_{it} - \beta_0 - \gamma l_{it} - \beta_k k_{it} - \beta_m m_{it} - g(\Phi_{t-1}(k_{it-1}, l_{it-1}, m_{it-1}) - \beta_0 - \beta_k k_{it-1} - \gamma l_{it-1} - \beta_m m_{it-1})|I_{it-1}] = 0 \quad (3)$$

where Φ_{t-1} is replaced by its estimate from the first stage. The coefficients $(\gamma, \beta_k, \beta_m)$ are estimated through a first-order Markov process.

TFP estimation results

For the construction and manufacturing sectors across the whole sample from 1970 to 2015 for 23 countries, Table 1 shows the equation (1) estimation results using the ACF estimation method and Table 2 shows the average share of the production factors in total expenditure.[8] There are two crucial points about the CS. First, the returns to scale are slightly decreasing, whereas they are moderately increasing in the MS. This situation may be a consequence of the organizational

Table 1. Production factor elasticity estimates.

Sector	Labor input (γ, the return to scale)	Capital intensity (β_k)	Intermediate input intensity (β_m)	Obs.
Construction	−0.02***	0.03***	0.77***	714
	(1.47e-07)	(1.47e-07)	(1.62e-07)	
Manufacturing	0.06***	0.11***	0.87***	707
	(1.47e-07)	(1.47e-07)	(1.62e-07)	

Robust standard errors in parentheses.
*** denotes significance at the 1% level; ** at 5% level; * at 10% level.
Country and year fixed effects included in all estimated specifications.

[7]The Wooldridge approach performs a nonlinear search on the unknown coefficients and functions, in contrast to the two-step approaches that perform a nonlinear search only on the labour and capital factors (Ackerberg, Caves, and Frazer 2015).

[8]We use the largest sample possible for the CS, thus the CS and MS estimation sample are not exactly the same. However, estimation results are not changed if we reduce the CS estimation sample to the size of the MS sample.

Table 2. Production factor sample average shares in total expenditure.

Sector	Labor	Capital	Intermediate inputs	Obs.
Construction	0.24	0.15	0.61	714
Manufacturing	0.17	0.13	0.70	707

structure of the CS. In other words, the big firms are so large that there are barriers to competition. The market structure is close to an oligopoly. This is supported by Lowe's (1987) conclusion that CS deviates significantly from the competition in Great-Britain and then Budiwibowo et al. (2009) and Kroft et al. (2020) which also raise this lack of competition in Indonesia and the US respectively.

Second, capital intensity elasticity is very low in the CS. A 100% increase in capital intensity – all things being equal – will lead to an increase in labour productivity of only 3%. Low elasticity of capital comes as no surprise since the CS is very labour intensive. However, the estimated capital elasticity in the CS is much lower than its 15% share in total expenditure, whereas estimated capital elasticity and share in expenditure are very close in the MS. Contrary to capital intensity, the intermediate input intensity estimated elasticity of 0.77 is higher than its 61% share in total expenditure in the CS. These differences between the estimated elasticities and the observed shares may be explained by market imperfections in the CS and the widespread practice in this sector of relying essentially on rented plant and equipment.[9] This emphasizes both the need to use gross output rather than value added and estimated elasticities rather than calibrated values when assessing the CS TFP. It also underlines the need for caution when interpreting the difference between CS and MS in terms of capital and intermediate input contributions.

Analysis of CS productivity

Figure 3 shows the average TFP growth over the period 1995–2015 for each country, for the construction and manufacturing sectors. This figure could be compared to Figure 1 which focuses on labour productivity growth. The differences in TFP among countries are correlated to the differences in labour productivity, especially for the CS with a correlation coefficient of 0.81, as against 0.55 for the MS. Figure 3 shows also a lack of TFP growth in the CS, with a negative yearly growth of −0.1% on average for the whole sample, or a loss of 1.9% after our 20-year observation period, and even negative TFP growth for 16 countries, culminating in a 0.7% annual decrease in the U.S.A. However, it is worth noting that TFP growth is also weak in the MS, with an average yearly growth over the whole sample of 0.15% only, leading to a 3.1% TFP increase after 20 years. Therefore, we need to assess the different contributions of the production factors to the growth of the gross output per worker to properly understand the CS changes (Online Appendix D provides a more detailed presentation of the TFP).[10]

Figure 4 shows the TFP, capital intensity, intermediate input intensity, and labour contributions to the growth of gross output per worker over the period 1995–2015 for the construction and manufacturing sectors based on the estimates in Table 1. The total of the contributions, which is equal to growth in gross output per worker, is much higher in the MS than in the CS, with 3.6% and 0.84% per year, respectively. These growth rates can be mainly explained by the intermediate input intensity contributions, for 3.1% in the MS and 0.9% in the CS on average. For the CS, the sum of the other factor contributions is negative on average: we have already seen that TFP growth is negative (−0.1%), the negative return to scale is negligible (−0.01%), and the contribution of capital intensity is very small (0.05%), since capital elasticity is low. Over the same period, on average in the MS, the positive return to scale was also negligible (−0.06%), but in addition to the positive TFP growth (0.15%) there is also a positive contribution from capital intensity of 0.4%. Because of the practice in the CS of

[9]Se for instance Eccles (1981) study which shows that capital equipment needed for construction is generally owned by subcontractors and that equipment used is often rented..

[10]Our production function explains the gross output, using intermediate input as a production factor. It provides a better understanding of the changes occurring in the CS than can be achieved by using value added as the dependent variable of the production function. However, the shortcoming with this choice is that we cannot provide a direct analysis of labour productivity growth contributions.

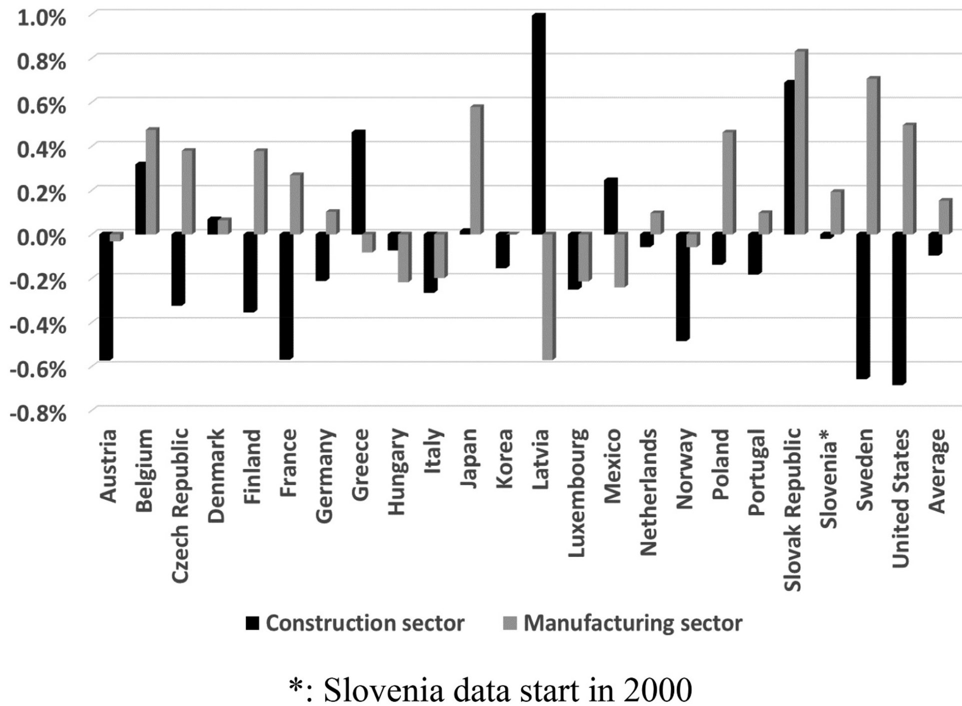

Figure 3. Average yearly TFP growth over the period 1995–2015.

renting costly plant, it is worthwhile adding the capital and intermediate input contribution to growth when making comparisons with the MS. The sum of these contributions is equal to 0.95% per year for the CS and 3.50% in the MS, so there is still a huge difference between the two sectors. These results emphasize that the biggest differences in growth between the construction and manufacturing sectors is not in terms of TFP, even if it is detectable (0.25% per year), but in terms of the capital and intermediate input intensity contributions.

IV. Regulatory impact

The CS is highly regulated, but there is no analysis in the literature of the effects of these regulations on productivity. In this section, we fill this gap and investigate whether regulatory reforms may boost CS productivity.

We estimate the effects of these regulations on labour productivity and on TFP, capital intensity, and intermediate input intensity. This allows us: (i) to test whether such regulations have an impact on labour productivity; (ii) to understand how these regulations may impact labour productivity; and (iii) to provide policy recommendations that may support the CS labour productivity. This section shows first the impact of regulations on labour productivity and then on TFP. Estimation results of the effects on capital and intermediate input intensity are provided in Online Appendix F, as we find no significant effect on these variables.

Figure 5 shows a negative relation in the CS between the number of procedures and its productivity, in terms of labour productivity as well as TFP. However, this effect must be confirmed by estimates taking account of individual heterogeneity, unobserved common factors, and of other variables that may be correlated with the CS regulations.

Estimated equation

The estimated equation for the impact of regulations on CS productivity is the following:

$$ln(y_{it}) = \alpha_0 + \alpha_1 \ln(REG_{it}) + \sum_k \alpha_k x_{it}^k + \delta_i + \delta_t + u_{it}$$

Where lny_{it} is the natural logarithm of CS productivity, measured in terms of Labour Productivity (LP) or TFP, of country i in period t; REG is one of the 'Doing Business project' regulation indicators (several indicators may also be introduced

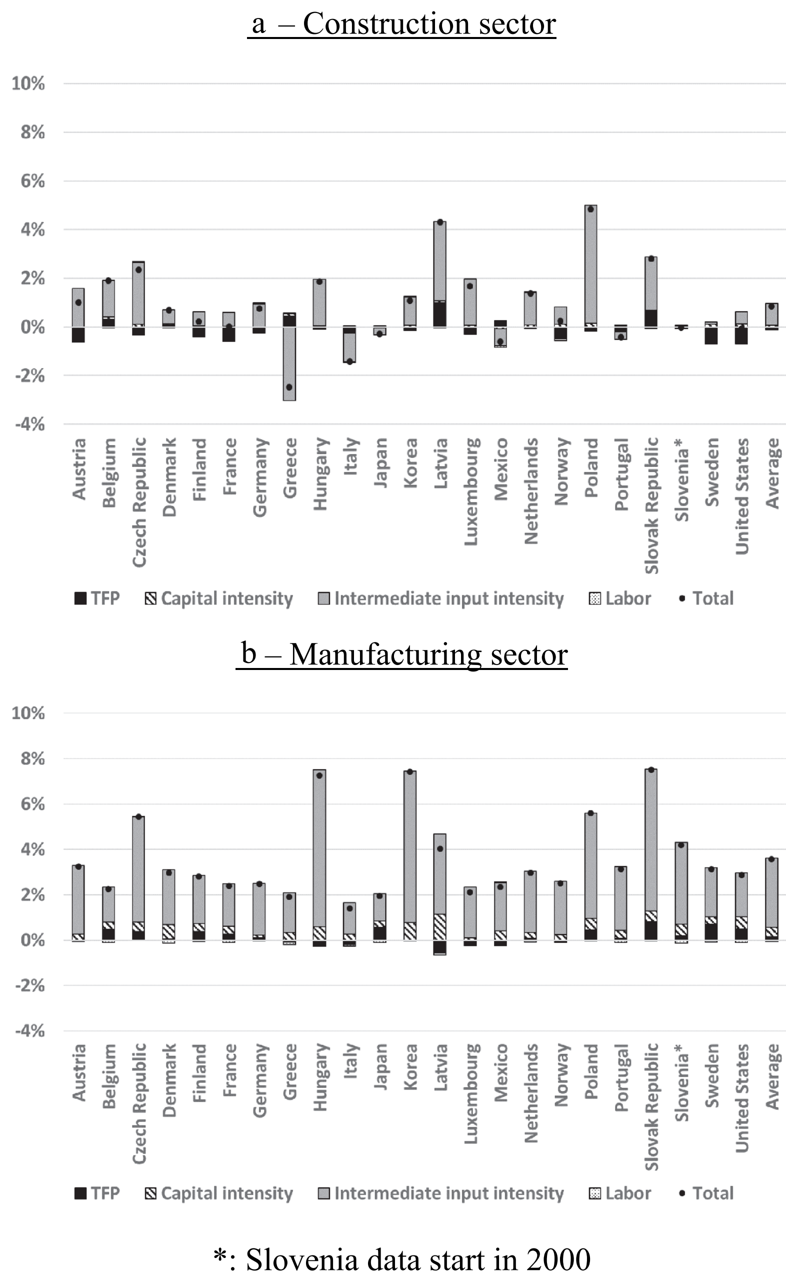

Figure 4. Average contributions to the yearly growth in gross output per worker over the period 1995–2015.

simultaneously); x^k are control variables; δ_i, δ_t, and u_{it} are respectively country fixed-effects, year fixed-effects, and random error terms. The control variables are various other regulations, as mentioned in section 2.2., as well as the natural logarithm of productivity (labour productivity or TFP) in the MS.

We use productivity in the MS as control variable because if an economic shock affects the country, this will of course modify the productivity of all sectors, including construction, but it may also modify the regulations because the government may react to this economic shock by regulatory change. If this is the case, it will induce endogeneity in the explanatory variable (omission bias) and we introduce the MS productivity in order to prevent such bias.[11] As MS productivity

[11]Taking into account the country's productivity as an explanatory variable would allow for this shock, but the country's productivity includes the CS, which would be a new source of endogeneity. Moreover, productivity in the services sector is quite difficult to measure, so we might as well account for the country's shock through the best productivity measurement, that of the manufacturing sector.

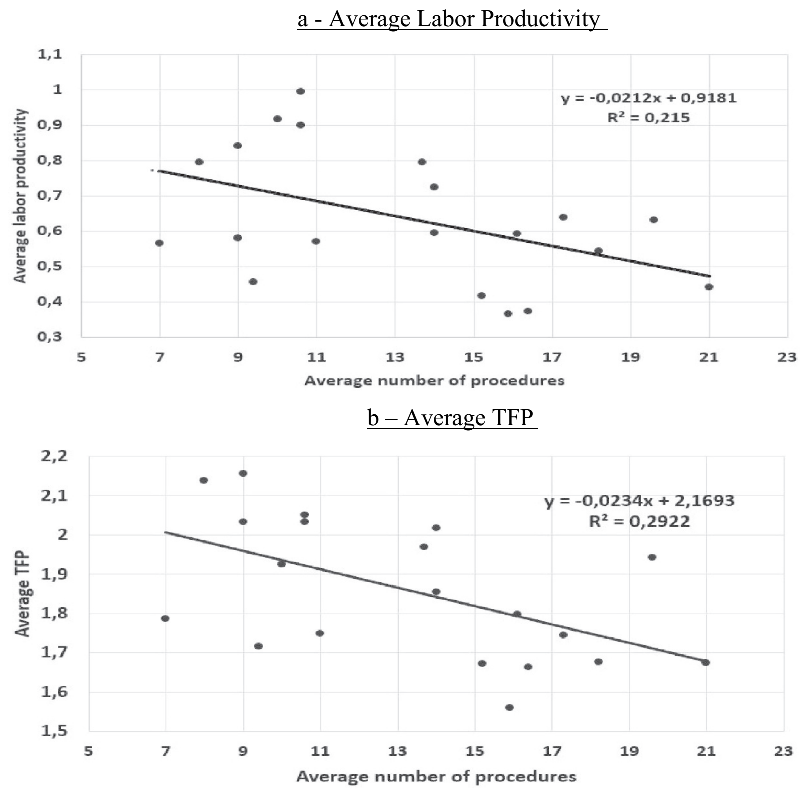

Figure 5. Relation between the “number of procedures” and CS productivity.

Table 3. Estimated productivity impact of the number of procedures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep var.	Labor Productivity (log)				TFP (log)			
Sample	Construction sector		Manufacturing sector		Construction sector		Manufacturing sector	
Number of procedures (log)	−0.57**	−0.46**	−0.22	0.12	−0.13***	−0.10*	−0.04	−0.05
	(0.22)	(0.18)	(0.16)	(0.21)	(0.04)	(0.06)	(0.03)	(0.05)
MS LP (log)		0.34***						
		(0.09)						
MS TFP (log)						0.05		
						(0.16)		
CS LP (log)				0.36***				
				(0.10)				
CS TFP (log)								0.02
								(0.07)
ETCR		0.14***		−0.10		0.01		0.003
		(0.04)		(0.06)		(0.01)		(0.02)
Government size		0.03		0.04		0.01		0.02
		(0.03)		(0.04)		(0.01)		(0.01)
Freedom to trade		0.16**		0.07		0.05**		−0.01
		(0.05)		(0.07)		(0.02)		(0.01)
Obs.	200	200	200	200	200	200	200	200
R^2	0.28	0.41	0.52	0.61	0.22	0.30	0.17	0.28

Standard errors reported in parentheses. ***, **, and * denote, respectively, statistical significance at 1, 5, and 10% levels.
Country and year fixed effects are included in all specifications.

makes allowance for possible economic shocks, we do not expect its estimated coefficient to correspond only to the true direct impact of MS productivity.

Impact of the number of procedures

Table 3 shows the estimated LP and TFP impact of the number of procedures required to build a warehouse. The number of procedures has a significant and negative impact on TFP in the construction sector, with or without control variables (cols 1, 2, 5, and 6). On the contrary, we find no significant effect of the number of procedures on the MS productivity (cols 3, 4, 7, and 8). This placebo test and estimation results including MS productivity (cols 2 and 6) confirm our conditional exogeneity assumption: the number of procedures ignores other country*year-specific factors.

Among regulatory indicators available as control variables, only the 'Freedom to trade' indicator makes a strongly significant impact on both Labour Productivity and TFP of the CS. According to our estimates, an increase in this indicator, so an increase in 'economic freedom', makes a significant positive impact on the CS LP and TFP. The 'ETCR' indicator has a strong impact on SC LP only, while 'Government size' has no impact on productivity in any sector. Labour productivity in both sectors is positively and significantly correlated, but TFP is not. Estimation results using alternative control variables are presented in Appendix E. The impact of the number of procedures is strongly robust to the set of control variables.

Lastly, the estimated effects on capital and intermediate input intensity are presented in Appendix F. We find a positive impact on capital intensity, but significant only at the 10% threshold, and no effect on intermediate input intensity. In terms of economic interpretation, we note that the level of TFP decreases in the CS when the procedures for completing all the formalities of building construction increase. The intensification of administrative procedures within the sector supposedly slows its economic performance because of probable barriers to entry for new firms. Since there is little competition in the sector, there is little incentive to improve efficiency. This leads to lower productivity due to the non-reallocation of resources or to the allocation of resources to unproductive tasks in presence of heavier regulations.

Impact of alternative indicators of CS regulations

Table 4 shows the estimation results on the TFP equation when using the different 'Doing Business Report' measures of the CS regulations. The total duration of the procedures required to build a warehouse has no significant impact on the CS TFP (cols 2 and 6). The total cost of the procedures has a slightly significant impact on the CS TFP (col 3) that disappears when we introduce the other indicators simultaneously (cols 4, 7 and 8). On the contrary, the effect of the number of procedures remains robust. These results may be explained by the difficulty in measuring the duration and cost of the procedures. Therefore, the number of procedures is our preferred measure of the CS specific regulations.

Simulation

As shown in section III, the weak labour productivity growth in the CS has a multifactor explanation: low or even negative TFP growth, and low capital and

Table 4. Estimated TFP impact of the alternative CS regulations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of proc. (log)	−0.13***			−0.10**	−0.10*			−0.10*
	(0.04)			(0.04)	(0.06)			(0.07)
Duration of proc. (log)		−0.02		−0.008		−0.01		−0.003
		(0.02)		(0.02)		(0.02)		(0.01)
Cost of proc. (log)			−0.01**	−0.005			−0.002	0.001
			(0.005)	(0.005)			(0.009)	(0.01)
MS TFP (log)					0.05	0.07	0.08	0.05
					(0.16)	(0.17)	(0.16)	(0.16)
ETCR					0.01	0.01	0.01	0.01
					(0.01)	(0.01)	(0.01)	(0.02)
Government Size					0.01	0.02**	0.02	0.01
					(0.01)	(0.01)	(0.01)	(0.01)
Freedom to trade					0.05**	0.06**	0.06***	0.05**
					(0.02)	(0.02)	(0.02)	(0.02)
Obs.	200	200	200	200	200	200	200	200
R^2	0.22	0.18	0.20	0.23	0.30	0.29	0.28	0.30

Standard errors reported in parentheses.
***, **, and * denote, respectively, statistical significance at 1, 5, and 10% levels.
Country and year fixed effects are included in all specifications.
Dependent variable: *TFP (log)*.
Sample: Construction sector.

intermediate input intensity contributions to growth compared with the MS. According to the estimation results, CS-specific regulations have an impact on TFP but not on factor intensities. This subsection is given over to simulating TFP gains due to regulation reforms in the CS in order to give economic significance to our estimation results. We compute the impact of a switch in all countries in 2015 to the 'lightest practices', i.e. the smallest number of procedures in our sample (Denmark with seven procedures), according to the estimated parameters shown in Table 3 column 6.

The simulation results are presented in Figure 6. The differences in effects among countries stem from their levels of 'excess' regulations in 2015. The average TFP gain is of 6.2%, which is very high. However, it should be interpreted as the long-run TFP gain from reforms that may be very ambitious in some countries. It is also important to notice that the number of procedures is only a proxy for the level of regulatory barriers in the CS. So, these TFP gains should correspond to reforms of CS regulations, not only to a reform of the number of procedures.

V. Conclusion

This paper confirms for a panel of 23 countries over the period 1995–2015 the lack of labour productivity growth in the CS already observed in the literature for a subset of countries. We investigate the sources of this lack of growth. First, using the ACF method, we measure TFP as well as production factor contributions to the growth of gross output per worker, showing a lack of TFP growth but also the weak contribution from capital intensity. Our estimations underline also the very low capital intensity elasticity in the CS. This is not a surprise since the CS is very labour intensive. However, the estimated elasticity of capital in the CS is much lower than its 15% share in total expenditure. This difference between the estimated elasticities and the observed shares may be explained by the market imperfections in the CS and the extensive reliance in this sector on renting plant and equipment. It emphasizes the need to use estimated elasticities rather than calibrated values when assessing the CS TFP, but also that further analyses are required to better understand this specificity of the CS.

Second, we find that CS sector-specific regulations may have a negative impact on TFP. The 'Doing Business project' indicator we use for the CS-specific regulations is available only for the period 2006–2015, so we are unable to calculate how much of the lack of productivity growth in the past decades can be ascribed to these regulations. Even for the available period, regulatory changes are too small to explain the phenomenon. Our results suggest that reducing the

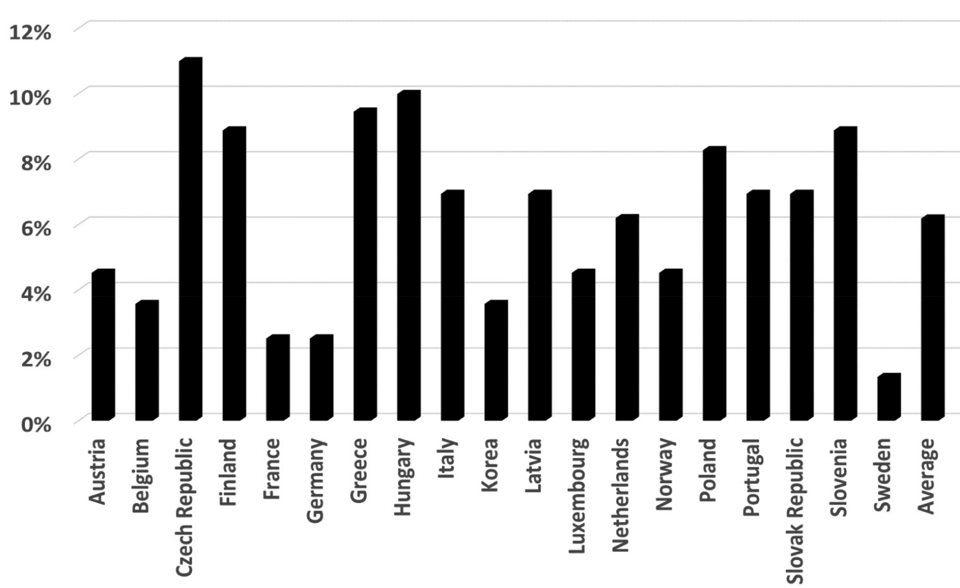

Figure 6. TFP gains arising from a switch toward the "lightest practices" in 2015.

number of CS regulations might bolster labour productivity. For instance, according to our estimation results, a switch of the regulations to the lightest practices would lead to a long-term TFP increase of 6% on average. In comparison, the CS TFP would have been 5% higher in 2015 if CS TFP growth had been equal to MS TFP growth over the whole 1995–2015 period.

Our study does not consider regulations related to the quality and safety of buildings and workers due to lack of data availability. This is an important limit of our paper as these regulatory aspects, which are crucial for CS, could enhance the performance of the sector, confirming Porter's (1991) hypothesis that strict environmental regulations can have a positive impact on productivity. An international survey of quality and safety regulations would be relevant to the knowledge of the construction sector and go over this limit.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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