Market Imperfections, Trade and Firm Performance

Angelos Theodorakopoulos*

Ghent University

November 29, 2016

[PRELIMINARY VERSION. PLEASE DO NOT CIRCULATE]

Abstract

In this paper I estimate the firm-level effect on productivity from frictions in the input market across various types of firms. Firm-level frictions in the capital and labor market are expressed as the wedge between their respective marginal revenue product and marginal cost. Introducing them, under a novel approach, in a standard model of production function estimation, I can directly estimate their effect on future productivity along with the parameters of the production function. I employ a rich dataset with firm-level information from the manufacturing sectors of 16 EU countries during 1998 to 2007. On the one hand, firms facing increased labor market frictions experience increases in their future productivity that are smaller for exporters. It suggests that domestic firms are less willing to incur the costs associated with adjusting their workforce (tangibles). Hence they rely relatively more on internal reorganisation and improvement of managerial practices (intangibles) that increase their future productivity via learning mechanisms. On the other hand, productivity effects from capital market frictions are less prevalent and uniform across all types of firms, pointing to the less-flexible and more-costly to adjust nature of capital.

Keywords: Labor and capital market imperfections, adjustment costs, total factor productivity, learning
JEL classification: D22, D24, D83, F14, F16, L25

*Corresponding author: Department of Economics, Ghent University, Tweekerkenstraat 2, B-9000 Ghent, Belgium, e-mail: angelos.theodorakopoulos@ugent.be
I thank participants at DEGIT Sept 2016 and ETSG Sept 2016 for their comments and suggestions. Special thanks are extended to Sotiris Blanas, Ruben Dewitte, Bruno Merlevede, Peter Neary, Nina Pavcnik, Glenn Rayp, Ariell Reshef, Mark Roberts, Johannes Schmieder, Felix Tintelnot and Gonzague Vannoorenberghe.

1 Introduction

Firms adjust their demand for inputs more slowly than the shock to input demand would suggest. This sluggishness is mainly attributed to two sources of input market frictions. The first is from input market reforms implemented by governments i.e. firing/hiring costs, unemployment benefits, minimum wage, working time, employment protection, payroll tax rate, labor unions, access to finance and changes in the extent of subsidies to new investment in capital equipment. The second is from general characteristics of the input market environment as perceived by each firm i.e search and match frictions, labor market mobility, installation cost of new capital, learning of new technologies, indivisibilities in capital, training costs, screening process of employees and costs of posting vacancies. Therefore, even firms operating in economies with the most flexible input markets will face adjustment costs that will impact both firm level and aggregate outcomes (Hamermesh and Pfann, 1996).

The literature started focusing on the introduction of input market rigidities in order to explain patterns on aggregate variables. Such variables were employment, unemployment, job turnover, wages, investment, dinvestment and capital irreversibilities with observed discrepancies across countries, which models under homogeneous and perfect labor market assumptions failed to explain.[1] Concurrent developments in theoretical modelling have provided researchers with the appropriate tools to model the role of specific input market rigidities (i.e search and matching frictions or severance payments) on firm level decisions and dynamics.[2]

International trade literature has also benefited from this advancement by incorporating labor market frictions in trade models with firm level heterogeneity. These models provide a theory based explanation on how specific types of labor market rigidities (i.e search frictions, matching frictions or severance payments) in an economy with trade and trade frictions, can explain patterns observed in the data. However, the focus so far has been on outcomes such as employment, unemployment, investment, wage inequality and welfare changes within and between industries or countries.[3]

In the majority of the aforementioned literature, theory would suggest that input market rigidities can be seen as a financial constraint that negatively affects firm's investment decisions. Consequently, it would negatively impact its productivity as well. This negative relationship is amplified from the interaction with trade and trade frictions.[4] However, all these models still simplify to labor productivity and results are driven from specific types of input market rigidities. What is more, most of the empirical work is at the aggregate level and with no robust results at the micro level. This difficulty arises from the fact that most theoretical models can accommodate only one type of input market rigidity at a time, for example matching frictions. This excludes other possibly equally significant interacting sources of rigidities, such as search frictions or severance payments. One exception is Dobbelaere and Vancauteren (2014) that use a flexible approach, but still focus on labor market frictions at the industry level masking possible heterogeneity and interaction effects with capital market frictions. In total, both theoretical and empirical literature have not yet introduced a consistent way of unifying all possible input market rigidities in a firm-level measure. Therefore, it reduces our flexibility to characterise their total impact on firm level performance.

I bridge this gap by estimating at the firm level the impact of input market frictions on firm performance. Exploiting the optimal decisions from the dynamic problem of a firm

[1]See non exhaustive list: Hopenhayn and Rogerson (1993); Hobijn and Şahin (2013); Aguirregabiria and Alonso-Borrego (2014); Lagos (2006); Alvarez and Veracierto (2001).

[2]See: Dustmann et al. (2009); Card et al. (2012); Koeniger and Prat (2007); Autor et al. (2007).

[3]See: Helpman et al. (2010b,a, 2011, 2016); Egger and Kreickemeier (2009); Felbermayr et al. (2011, 2014); Helpman and Itskhoki (2010); Fajgelbaum (2013); Coşar et al. (2016).

[4]There is also a negative impact on firm level dynamics i.e. reduced probability of engagement in exporting, FDI and increased probability of firm exit. For employment, wages and welfare results are mixed and depend on characteristics of the country, industry and firm.

with adjustment costs, I capture frictions for the non-freely adjustable inputs as the wedge between their respective marginal revenue product and marginal cost. This wedge departs from the neoclassical setup of freely adjustable inputs since it is driven by the presence of adjustment costs. This allows me to express frictions in the labor and capital market as a function of variables typically observed in most micro-level datasets and parameters of the production function.[5] Heterogeneity is expected since firm characteristics (i.e training costs for new employers, composition of labor in the firm, installation time for new capital, posting of new vacancies, screening process of employees, mobility costs of employees etc.) will shape idiosyncrasies on firm's cost functions. This would be true even in the case where all policy related input market rigidities apply at the country level. In total, these measures can be considered as an indicator of how costly it is for each firm to adjust its non-freely adjustable inputs, directly reflecting the level of frictions in the input market.

The novelty of the approach lies on the fact that by introducing these measures in any typical semi-parametric model of production function estimation, I can directly estimate the effects on the future productivity of firms from labor (henceforth LMF) and capital (henceforth KMF) market frictions, together with the parameters of the production function technology.[6] Empirically I model potential productivity effects from rigidities in the input market as a learning process, by allowing past experience from labor and capital market frictions to affect future productivity similar to Aw et al. (2008); De Loecker (2013).

For the analysis, I employ a rich dataset with firm-level information from the manufacturing sectors of 16 EU countries during 1998-2007. The extensive data-coverage across EU, allows me to draw conclusions with external validity and also uncover possible patters by exploiting variation across countries and industries.

On the one hand, I find that increases in labor market frictions positively affect the future productivity of firms. This is in line with the idea that during periods of increased rigidities in the labor market firms face higher costs for adjusting labor (i.e reduced probability of adjusting labor). Therefore, they are forced to find alternative channels to substitute the costly adjustment of labor in order to meet demand for their final output. Such channels include reorganising their structures and improving management practices. Overall the increase in future productivity of firms comes from the more efficient use of intangible inputs due to the slow or non-adjustment of tangible inputs i.e labor.

On the other hand, increases in capital market frictions do induce significant productivity effects but are less prevalent and strong than before. In periods of increased capital market frictions it is very costly for firms to replace or update their existing capital. Therefore, they have to come up with ways to reconfigure their existing capital in order to make their production processes more productive to meet demand. However, productivity improvements via this channel are less prevalent compared to the case of labor. This is reconciled with the less-flexible-to-adjust nature of capital (tangible fixed assets) compared to labor, especially in the manufacturing sector, where production lines face capacity constraints that can mainly be relaxed when firms undertake new investments (i.e new machineries or upgrade of production processes), while labor can be reorganised in a more flexible way by reassigning tasks or responsibilities and restructuring management hierarchies within the firm.

For a few industries I also find a negative impact of capital market frictions on future productivity, meaning that firms will be able to increase their performance only once capital

[5] This idea is not new in the literature. It is in line with the work of Petrin and Sivadasan (2006, 2013) that use the gap as a statistic to measure economic inefficiency from the presence of non-neoclassical components i.e., hiring, firing and search costs, capital adjustment costs, taxes and subsidies, hold-up and other contracting problems, non-optimal managerial behavior and markups. Also, it is conceptually similar to the seminal work of Caballero and Engel (1993) where they show that the gap between the observed and forecasted optimal level of employment is related to the probability of adjusting labor. For more on the gaps see Gali et al. (2007); Eslava et al. (2010); Caballero et al. (2013).

[6] Under further assumptions and structure this approach can also be applied on dynamic panel methods.

market frictions are reduce. This way firms can incur the costs associated with adjusting capital via the introduction of better production processes that reduce x-inefficiencies and at the same time allow labor to be more productive. By default, these firms face structural constraints that do not allow them to reconfigure the existing capital. Therefore when capital is extremely inflexible and costly to adjust firms can only improve their productivity once capital market frictions are milder i.e lower costs associated with adjusting capital.

For a few industries I also find a negative impact of capital market frictions on future productivity. For these firms adjusting capital is such a costly activity that they will undertake it only when capital market frictions are reduced. At the same time there is no room for reconfiguring the existing capital since This way firms are more willing to adjust capital i.e introduction of better production processes and machineries, leading to reduction in x-inefficiencies and at the same time allowing labor to be more productive.

Continuing I find that the future productivity of exporters increases by less compared to that of non-exporters when facing increased labor market frictions. Openness makes firms more willing to incur the costs associated with adjusting their workforce (Coşar et al., 2016). Therefore, compared to non-exporters, they are less likely to reorganise their existing workforce that would result in relatively larger increases in future productivity. However, no significant effects appear when interacting capital market frictions with exporting behaviour, pointing again to the non-flexible to adjust nature of capital. On average, both exporting and non-exporting firms are equally constrained from capital market frictions.

The remainder of this paper is organised as follows: in Section 2 I first provide an overview on how I model imperfections in the input market. I then describe how I retrieve a firm-level measure that captures the presence of frictions in the capital and labor market. In Section 3, I provide the empirical methodology for identifying the productivity effects from labor and capital market frictions and in Section 4 I describe the data. Section 5 presents the main results and a number of robustness checks. Finally, Section 6 offers some concluding remarks.

2 Market Imperfections

To introduce imperfections in the input market I add adjustment costs in a dynamic model of the firm. From the optimal decisions of the firm I can express labor and capital market frictions as the respective wedge between the marginal revenue product and marginal cost. This section provides the main steps and assumptions needed. For a detailed analysis see Appendix A.

Using capital K_{it}, labor L_{it} and material M_{it} inputs, firms produce a non-storable output that is supplied in the output market under imperfect competition.[7] Subtracting production costs from revenue I get the firm's profit function:

$$\begin{aligned}\Pi_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}, M_{it}) =& R_{it}(A_{it}, K_{it}, L_{it}, M_{it}) - P_{it}^I I_{it} - P_{it}^L L_{it} - P_{it}^M M_{it} \\ & - C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it})\end{aligned} \tag{1}$$

where $R_{it}(\cdot)$ is the firm's revenue function, P_{it}^I is the direct purchase price of new capital, P_{it}^L is the wage offered to hire one unit of employment, P_{it}^M is the material price, $C_{it}(\cdot)$ is the cost of adjusting the non-freely variable inputs capital and labor and A_{it} is a profitability shock reflecting productivity and demand shocks.

Adjusting the non-freely variable inputs, in this case capital and labor, entails costs that are represented by the adjustment cost function $C_{it}(\cdot)$ which is firm-time specific, convex and covers both the cases of simultaneous and sequential adjustment of capital and labor. Therefore, it

[7]In this section I consider the case of imperfect competition since from a theoretical point of view the existence of markups can substantially influence the measures of capital and labor market frictions. However, for the main estimations I consider an environment of perfect competition as the limit case of imperfect competition, where markups are zero, since it is computationally less intensive and results remain similar as shown in the robustness section.

includes any possible implicit and explicit cost that arises from both the conditions in factor markets and any government policies affecting the firm's path of optimal factor demand. Overall, instead of a particular model of adjustment costs, such as one based on search frictions (Cooper et al., 2007), I employ a more general approach that covers any possible type of adjustment cost but is agnostic about the exact source of adjustment frictions.

Capital is a dynamic input that is quasi-fixed, since the choice for new capital is made in the previous period $t-1$, while it only becomes productive in period t (time to adjust new capital) and faces adjustment costs. Capital accumulates, with probability one, according to $K_{it} = (1-\delta_{it})K_{it-1} + I_{it-1}$, where δ_{it} is the rate of capital depreciation and I_{it-1} is the investment in new capital. Labor is also a dynamic input but more flexible than capital, since it is both chosen and becomes productive within period t (no whole period to adjust labor) but also faces adjustment costs. Materials is a static (i.e., freely adjustable or variable) input since it faces no adjustment costs or period lag.

Firms decide the optimal factor demand. This involves the choice for accumulation of capital, hiring/firing labor and purchase of material inputs. Decisions are made in a discrete time setting in order to maximize the expected net present value of future cash flows. The Bellman equation of the firm's dynamic programming problem is:

$$\begin{aligned} V_{it}(S_{it}) &= \max_{K_{it+1}, L_{it}, M_{it}} \{\Pi_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}, M_{it}) + \beta E[V_{it+1}(S_{it+1})|J_{it}]\} \\ &= \max_{K_{it+1}, L_{it}, M_{it}} \{R_{it}(A_{it}, K_{it}, L_{it}, M_{it}) - P^I_{it} I_{it} - P^L_{it} L_{it} - P^M_{it} M_{it} \\ &\qquad - C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}) + \beta E[V_{it+1}(S_{it+1})|J_{it}]\} \end{aligned} \tag{2}$$

where $V_{it}(\cdot)$ denotes the maximised value for firm i in period t, $S_{it} = \{A_{it}, K_{it}, L_{it-1}\}$ is the vector of state variables, β is the discount factor and $E[\cdot]$ denotes the expected value conditional on information available in period t (J_{it}). The expectation is taken over the distribution of profitability shocks.[8]

In the case of a static input i.e, materials the model boils down to a static optimization problem since there is no forward looking behaviour. At an interior solution, conditional on the choice of dynamic inputs, the static first order condition (FOC) for materials is:

$$\theta^M_{it} \frac{P_{it} Q_{it}}{M_{it}} \left(1 - \frac{1}{\eta_{it}}\right) - P^M_{it} = 0 \tag{3}$$

where $\theta^M_{it} = \frac{\partial Q_{it}}{\partial M_{it}} \frac{M_{it}}{Q_{it}}$ is the output elasticity of materials and $\eta_{it} = \left|\frac{\partial Q_{it}}{\partial P_{it}} \frac{P_{it}}{Q_{it}}\right|$ is the absolute value of the price elasticity of the residual demand for firm i in period t. In this case the marginal revenue product of the static input is equal to its marginal cost.

The FOC for capital combined with the relevant envelope condition gives:

$$\begin{aligned} \beta E\Big[\theta^K_{it+1} \frac{P_{it+1} Q_{it+1}}{K_{it+1}} \left(1 - \frac{1}{\eta_{it+1}}\right) + (1-\delta_{it}) P^I_{it+1}\Big] - P^I_{it} \leq & \frac{\partial C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it})}{\partial K_{it+1}} \\ & + \beta E\Big[\frac{\partial C_{it+1}(A_{it+1}, K_{it+1}, K_{it+2}, L_{it}, L_{it+1})}{\partial K_{it+1}}\Big] \end{aligned} \tag{4}$$

where the first component of the right hand side is the marginal cost of adjusting new capital and the second component is the cost advantage on adjusting capital tomorrow from adjusting capital today. Therefore, the right hand side captures the contribution of the adjustment costs

[8] The uncertainty about the future arises because A_{it} evolves probabilistically. We assume that the profitability shocks evolve probabilistically following a first order Markov process. Note that I allow the distribution of future productivity to be dependent not only on current productivity but also on other possible factors such as tightness in the labor or capital market, exporting status, etc., that will later on be the key components of our estimation strategy.

on optimal investment policy. It is clear that the presence of adjustment costs generates a wedge between the expected marginal revenue product and the marginal cost of new capital. Alternatively, it can be seen as the difference between the direct and shadow price of capital.

Similarly, for the case of labor:

$$\begin{aligned}\theta^L_{it}\frac{P_{it}Q_{it}}{L_{it}}\left(1-\frac{1}{\eta_{it}}\right)-P^L_{it}\leq & \frac{\partial C_{it}(A_{it},K_{it},K_{it+1},L_{it-1},L_{it})}{\partial L_{it}}\\ & +\beta E\Big[\frac{\partial C_{it+1}(A_{it+1},K_{it+1},K_{it+2},L_{it},L_{it+1})}{\partial L_{it}}\Big]\end{aligned} \tag{5}$$

where the right hand side captures the marginal costs of adjusting labor. As before, the costs for adjusting labor drive a wedge between the marginal revenue product and marginal cost of labor. Equivalently this wedge is the difference between the wage of workers and their shadow wage.

Both expressions hold with inequality because of the possibility of corner solutions i.e., non-adjusting firms. On the one hand, when firms adjust both capital and labor, expressions hold with equality. On the other hand, when at least one of the factors does not adjust, expressions hold with inequality. The inequality shows that at any other attainable level of the factor that is not adjusted, the marginal cost of adjusting is not equal to the marginal benefit.

Overall, I see in both expressions that adjustment costs drive a wedge between the marginal revenue product and marginal costs of the non-freely adjustable inputs. This is represented in the right hand side of (4) and (5). In this case, the wedge captures any possible friction in labor and capital markets that do not allow firms to freely adjust their factors.

Given that I do not know the exact nature of adjustment costs and therefore their functional form, I cannot estimate this wedge from the right hand-side of expressions (4) and (5). However, from the left hand side I can express this wedge as a function of variables observed in the data and parameters to be estimated. It is important to mention that in the case of firms not adjusting at least one of the non-freely variable factors, these effects will be captured at a lower bound ($\leq$).

From rearranging (4), I express frictions in the capital market as 'experienced' by firm i in period t (henceforth KMF):

$$KMF_{it}(\theta^K_{it},\beta,\delta_{it})=\left|\theta^K_{it}\frac{P_{it}Q_{it}}{P^I_{it}K_{it}}\left(1-\frac{1}{\eta_{it}}\right)+(1-\delta_{it})-\frac{P^I_{it-1}}{\beta P^I_{it}}\right| \tag{6}$$

Because of the time to adjust aspect of capital, the firm will fully observe the benefits and costs from adjusting capital only in the period that the new capital becomes productive. This is because there are costs and benefits that evolve between the period that the new capital is chosen $(t-1)$ and the period it becomes productive (t). Since the choice for capital was made in the previous period, I also need to give a premium to the past period's values and thus divide all terms with the discount factor β. To control for the fact that the gap is measured in monetary values I divide (4) with P^I_{it}. This way, the expression represents the share of marginal costs of adjustment over the direct cost of new capital. The absolute value allows me to include in one measure both the cases of firms investing or disinvesting.Overall, it is a uniteless measure of frictions in the capital market that is a function of variables retrieved from the data and parameters to be estimated or recovered from the literature.

From rearranging (5), I express frictions in labor market as 'experienced' by firm i in period t (henceforth LMF):

$$LMF_{it}(\theta^L_{it})=\left|\theta^L_{it}\frac{P_{it}Q_{it}}{P^L_{it}L_{it}}\left(1-\frac{1}{\eta_{it}}\right)-1\right| \tag{7}$$

Since labor adjusts within the period, the direct costs and benefits of labor are observed by the firm during this period. Similar to the case of capital, I express the gap as a share of the per-period average wage P^L_{it}. The absolute value treats symmetrically the gaps from net hires and fires. Overall, it is a uniteless measure of frictions in the labor market that is expressed as a function of variables retrieved from the data and parameters to be estimated.

Overall, I have constructed a statistic that measures the presence of frictions in the labor and capital market. It is a uniteless measure specific to each firm-period and is expressed as a function of variables retrieved from the data and parameters to be estimated. It is an inherently relative measure that is interpreted as: firms with larger values of KMF_{it} (LMF_{it}) face relatively more frictions in the capital (labor) market i.e., more stringent.[9] As prementioned this measure includes all types of frictions that are present in the capital and labor market and also the way that each firm experiences them in each period.

3 Empirical Methodology

The effects of capital and labor market frictions on future productivity are estimated by introducing, in a novel way, the relevant measures of frictions into a typical production function estimation procedure. This section serves as an overview of the steps and assumptions needed. For a detailed description see Appendix B.

I consider a flexible gross output production function $Y_{it} = F(K_{it}, L_{it}, M_{it})e^{\omega_{it}+\epsilon_{it}}$, with Hicks-neutral productivity ω_{it} (alternatively TFP). In logs, the production function to be estimated is of the following form:

$$y_{it} = f(k_{it}, l_{it}, m_{it}) + \omega_{it} + \epsilon_{it} \tag{8}$$

where y_{it}, k_{it}, m_{it} are log values of deflated at the industry level operating revenue, capital and material respectively and l_{it} is the log of total number of employees for firm i at time t. Productivity ω_{it}, is unobserved by the econometrician but known to the firm. Shocks ex-post to firm's decisions and production are picked up by ϵ_{it}.[10]

To estimate the production function, I choose the simple nonparametric estimator for gross-output production functions with at least one flexible input proposed by (Gandhi et al., 2013). They establish identification by exploiting information in the first order condition with respect to the flexible input from the firm's static profit maximization problem. This flexible approach controls for both transmission and value-added bias. It imposes no specific functional form for the production function. In addition, it does not rely on strong assumptions imposed from alternative proxy variable frameworks. An example is the assumption of scalar unobservability or bijection, necessary to invert the proxy demand function (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Ackerberg et al., 2006; Wooldridge, 2009). In line with most of the the proxy variable methods the procedure follows two-steps. Overall, it exploits information within the model to secure identification for gross output production functions with at least one flexible input of production.[11]

For the core analysis I consider the classic environment of perfect competition in both input and output markets. Capital is a quasi-fixed input and therefore chosen one period prior to the realisation of productivity. Rigidities in the labor market, induce high labor adjustment costs but firms still adjust their labor within the period. Therefore, labor is a dynamic input but more flexible than capital since it is chosen during the productivity realisation. The only flexible

[9] Petrin and Sivadasan (2006, 2013) consider a similar measure of economic inefficiency for the special case of firing costs but keep it in monetary units.

[10] Given that y_{it} is a variable observed in our dataset, I expect ϵ_{it} to also contain measurement error to output and prices. This is assumed to be symmetric across firms within each industry and therefore not affecting our estimation.

[11] For a detailed explanation over the sizeable effects on the patterns of productivity heterogeneity when wrongly identifying value-added instead of gross-output production functions, see Gandhi et al. (2013). Building on that, Merlevede and Theodorakopoulos (2016) stress the importance of such misspecification when estimating learning by doing effects.

input in our specification is material, assumed to freely adjust in each period (variable) and have no dynamic implications (static).

From the first step, I can compute productivity $\omega_{it}(\alpha)$ as a function of the parameters (α) of the respective production function technology $f(\cdot)$. I proceed in the second step by exploiting the assumption over the law of motion of productivity. Similar to the seminal work of Olley and Pakes (1996), an exogenous first order Markov process can be assumed, $\omega_{it} = g(\omega_{it-1}) + \xi_{it}$. However, exogeneity should be relaxed in order to accommodate the fact that productivity evolves endogenously in response to firm's actions (De Loecker, 2013; Doraszelski and Jaumandreu, 2013; De Loecker and Goldberg, 2014). I expect that actions undertaken by firms, in response to shocks, affect their productivity evolution. Such actions could be observed (R&D, exporting, FDI, etc.) or not (firms replace current managers by better ones or adopt better management practices and these actions are not reflected in changes in expenditures) by the econometrician. Therefore, the law of motion for productivity should be modified so as to explicitly allow for these actions to affect productivity.

On top of lagged productivity, lagged and observable decision variables for firm i in period t are also allowed to affect current productivity outcomes (in expectation):

$$\omega_{it} = g(\omega_{it-1}, lnKMF_{it-1}, lnLMF_{it-1}, s_{it-1}) + \xi_{it} \tag{9}$$

where $lnKMF_{it-1}$, $lnLMF_{it-1}$ is the log of the measure of frictions in capital and labor markets respectively, s_{it-1} captures other relevant controls[12] and ξ_{it} denotes the productivity innovation.[13]

I can now express the innovation of productivity $\xi_{it}(\alpha)$, as a function of the parameters of the respective production function technology, by nonparametrically regressing $\omega_{it}(\alpha)$ on $g\big(\omega_{it-1}(\alpha), lnKMF_{it-1}(\alpha), lnKMF_{it-1}(\alpha), s_{it-1}\big)$. The novelty of the approach is that as in the case of lagged productivity, the measures of capital and labor market frictions are expressed as functions of the parameters of the production function technology, since their respective output elasticities $\theta^K_{it}(\alpha)$ and $\theta^L_{it}(\alpha)$ are also functions of α's. Specifically, the log of the measures of capital and labor market frictions used in the estimations are expressed as:

$$lnKMF_{it}(\alpha, \delta_j) = ln\left|\theta^K_{it}(\alpha)\frac{P_{it}\widehat{Y}_{it}}{P^I_{it}K_{it}} - \delta_j\right| \tag{10}$$

$$lnLMF_{it}(\alpha) = ln\left|\theta^L_{it}(\alpha)\frac{P_{it}\widehat{Y}_{it}}{P^L_{it}L_{it}} - 1\right| \tag{11}$$

where $\widehat{Y}_{it} = \frac{Y_{it}}{exp(\widehat{\epsilon}_{it})}$ is the observed output Y_{it} corrected for the ex post shocks $\widehat{\epsilon}_{it}$ as estimated from the first step[14], $P^I_{it}K_{it}$ is tangible fixed assets, $P^L_{it}L_{it}$ is the cost of employees and $P_{it}Y_{it}$ is total sales.[15]

[12] More specifically $s_{it-1} = (FE_{t-1}, FE_j, FE_r, FE_c)$ includes time, industry (if estimated at the sectoral level), nuts2-region (if estimated at the industry or sectoral level) and country (if estimated at the EU level) fixed effects respectively.

[13] For the estimations, I use both a linear ($\omega_{it} = \rho_\omega\omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + s_{it-1} + \xi_{it}$) and second order polynomial ($\omega_{it} = \rho_\omega\omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + \rho_{\omega\omega}\omega^2_{it-1} + \rho_{\kappa\kappa}lnKMF^2_{it-1} + \rho_{\lambda\lambda}lnLMF^2_{it-1} + \rho_{\omega\kappa}\omega_{it-1}lnKMF_{it-1} + \rho_{\omega\lambda}\omega_{it-1}lnLMF_{it-1} + \rho_{\kappa\lambda}lnKMF_{it-1}lnLMF_{it-1} + \rho_{\omega\kappa\lambda}\omega_{it-1}lnKMF_{it-1}lnLMF_{it-1} + s_{it-1} + \xi_{it}$) approximation of $g(\cdot)$ with additive time fixed effects s_{it-1}. Fixed effects enter in an additive fashion in order to restrict the parameter space and improve the efficiency of the estimation. I abstain from reporting polynomials of third order since results are similar and estimation becomes computationally intensive.

[14] This correction is of great significance since potential inhomogeneities in the data could distort the magnitudes of the measures. Under the same concern, special attention is paid on how I trim the data and what method is employed.

[15] For both measures, since I assume that firms operate under perfect competition in the output market, $\eta_{it} \to \infty \Rightarrow \left(1 - \frac{1}{\eta_{it}}\right) = 1$. For the measure of capital market frictions, since I do not observe the direct price of investment P_{it}, I make the simplifying assumption that when the choice for capital is made, its price is approximately equal to its next period's discounted price i.e $P^I_{it-1} \approx \beta P^I_{it}$. Finally, the depreciation rate of capital

The second step proceeds with a standard GMM technique. The set of moments used are $E[\xi_{it}(\alpha) \otimes n'_{it}] = 0$, where n_{it} is the row vector of instruments containing capital (k_{it}), lagged labor (l_{it-1}) and combinations of the two up to the number of parameters to be identified. The orthogonality conditions, directly depend on the timing assumptions of inputs. Capital is assumed to be decided a period ahead and therefore orthogonal to the innovation in productivity. However, for labor I rely on lagged values since current labor is expected to react to shocks to productivity, and therefore $E[\xi_{it}(\alpha)l_{it}]$ is expected to be nonzero.

Within the second step, I can directly estimate the effects on future productivity of firms from labor $\frac{\partial g(\cdot)}{\partial lnLMF_{it-1}}$ and capital $\frac{\partial g(\cdot)}{\partial lnKMF_{it-1}}$ market frictions. This means that by exploiting the optimal decisions from the dynamic problem of a firm I capture frictions in the capital and labor market as a function of parameters of the production function technology that are directly identified within any typical semi-parametric model.

Recall that I identify all productivity effects as a learning process. Therefore, it is imperative to use time α_t, industry α_j and region α_r fixed effects that will account for macroeconomic shocks and aggregate structural differences between industries and regions respectively.

4 Data

I construct a firm-level panel of manufacturing firms from 16 EU countries[16] during 1998-2007 from the Amadeus database by Bureau van Dijk Electronic Publishing (2011) (BvDEP). BvDEP regularly updates the information set in Amadeus and monthly releases a DVD containing the latest information on ownership. Firms that exit the market are dropped from the DVD fairly rapidly. For a complete set of financial and ownership information over time, I use a time series of (annual) DVDs to construct a consistent database. This allows me to build a dataset with nearly full financial and administrative information i.e. balance sheet, profit and loss account, activities, location, ownership, exit and entry. See Merlevede et al. (2015) for further details on the construction and representativeness of the data.

I focus on the sample of active manufacturing[17] firms that file unconsolidated accounts.[18] I retain firms reporting operating revenue, tangible fixed assets, number of employees, costs of employees, material inputs, NACE 2-digit level industry classification, NUTS 2-digit region classification, date of incorporation, and ownership information.[19] I remove outliers using the BACON method proposed by Billor et al. (2000).[20] Firms re-entering are removed from the sample, as are firms with less than three years of data. This results in an unbalanced panel of 146268 firms and 992047 observations for 16 EU countries during the period 1998-2007 (see Table 2).

Monetary variables are deflated using the appropriate NACE 2-digit output deflator from the EU KLEMS database. Real output (Y), is operating revenue deflated with producer price indices. Capital (K), is tangible fixed assets deflated by the average of the deflators of the following NACE 2-digit industries: machinery and equipment (29); office machinery and computing (30);

δ_j is computed from the data as the total amount of depreciation and amortization of the assets over total assets. I use total instead of fixed assets since the numerator contains depreciation of both intangibles, other assets and amortization. To avoid outliers and missing values, I use the mean values across firms within each industry j. XXXXXXXHOW much it varies?

[16]This includes Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Germany (DE), Estonia (EE), Spain (ES), Finland (FI), France (FR), Croatia (HR), Italy (IT), Norway (NO), Poland (PL), Romania (RO), Sweden (SE), Slovenia (SI) and Slovakia (SK).

[17]Table 1 in Appendix C provides an overview of the NACE 2-digit rev.1.1 industries included.

[18]Accounts not integrating the statements of controlled subsidiaries or branches of the concerned company.

[19]For FR I also have information on exporting revenues.

[20]BACON stands for block adaptive computationally efficient outlier nominators. It is a multiple outlier detection method. The variables I consider in the method are log values of output, labor, capital and material input. The procedure is each time applied at the level of the estimation i.e industry-country, country, industry-EU or EU specific.

electrical machinery and apparatus (31); motor vehicles, trailers, and semi-trailers (34); and other transport equipment (35) (Javorcik, 2004). Real material inputs (M), is material inputs deflated by an intermediate input deflator that is constructed as a weighted average of output deflators where country-time-industry specific weights are based on intermediate input uses retrieved from input-output tables. Labor (L), is the number of employees. 'Firm' wage (W) is measured as the ratio of cost of employees to the number of employees. I make sure that, if applicable, the minimum wage concept holds in all countries.[21] Finally, multinational status (MNC), is a dummy variable that indicates whether at least 10% of a firm's shares are owned by a single foreign firm. Table 2 shows summary statistics for the firms in our sample.

5 Results

In this section I first report the basic results on the productivity effects of labor and capital market frictions in Tables 3-4, using the approach detailed in Section 3. Finally, in Tables 5-X I present the productivity effects when input market frictions interact with trade and trade frictions.

5.1 TFP Effects from Labor and Capital Market Frictions

In Table 3, each line reports the productivity effect of labor market frictions from separate estimations at the industry level including all 16 EU countries. The first column reports the average estimated effect for a linear approximation of equation (9), while the last four columns report the average, 25th, 50th and 75th percentile from the distribution of estimated effects when considering a second order polynomial approximation.[22] I observe that an increase in labor market frictions (LMF) leads to a significant and positive increase in future productivity for the majority of industries. Since higher market rigidities translate to higher costs of adjusting labor, firms need to utilise their existing labor force in a more efficient way in order to meet demand for their output. Possible mechanisms include the reorganisation of firm, better management practices and reassignment of tasks across employees.

In Table 3, I report the productivity effects from capital market frictions using the same estimations from above. I observe that an increase in capital market frictions (KMF) leads to a significant and positive increase in future productivity. In periods of increased capital market frictions it is very costly for firms to replace or update their existing capital. Therefore, they have to come up with ways to reconfigure their existing capital in order to make their production processes more productive to meet demand.

However, productivity improvements via this channel are less prevalent compared to the case of labor. This is reconciled with the less-flexible-to-adjust nature of capital (tangible fixed assets) compared to labor, especially in the manufacturing sector, where production lines face capacity constraints that can mainly be relaxed when firms undertake new investments (i.e new machineries or upgrade of production processes), while labor can be reorganised in a more flexible way by reassigning tasks or responsibilities and restructuring management hierarchies within the firm. For the Manufacture of wearing apparel; dressing and dyeing of fur, I find a negative impact of capital market frictions on future productivity, suggesting that firms will be able to increase their future productivity once capital market frictions are reduced via the

[21]For BE ,BG, CZ, EE, ES, FR, PL, RO, SI and SK I apply the statutory minimum wage as reported in (OECD, 2015). Firms with a 'firm' wage less than the statutory minimum wage are dropped from the sample. For DE, FI, NO and SE with no statutory minimum wage concept (collective bargaining and unions) I assume a minimum wage for 1998 on 650 Euros/month growing by 50 Euros annually reaching 1150 Euros in 2007. Since there are no data for Italy I use Spain's statutory minimum wage as a proxy. Finally, there are no data available for the case of Croatia and therefore I keep all firms with at least 20 Euros/month for all years in the dataset.

[22]A third order polynomial is also considered, but results are not reported due to space considerations given that the effects are similar.

introduction of new production processes that reduce x-inefficiencies and allow also labor to be more productive.

5.2 TFP Effects from Labor and Capital Market Frictions with Trade

In this section I interact labor and capital market frictions with the exporting status of the firm.[23] From Table 5, I see that labor market frictions are in line with the results presented above while increased capital market frictions negatively affect future productivity. Firms in Croatia's developing economy can only increase their future productivity over time once they face less frictions in the capital market i.e it is less costly to adjust new capital, that will in turn improve their production lines and hence performance. Continuing, I observe a typical learning by exporting effect where a firm's performance improves after entering export markets as in De Loecker (2013).[24]

The future productivity of exporters increases by less compared to that of non-exporters when they face increased labor market frictions. Openness makes firms more willing to incur the costs associated with adjusting their workforce (Coşar et al., 2016). Therefore, compared to non-exporters, they are less likely to reorganise their existing workforce that would result in relatively larger increases in future productivity. Interacting capital market frictions with the exporting status results on a negative but statistically insignificant effect, pointing again to the non-flexible to adjust nature of capital. On average, both exporting and non-exporting firms are equally constrained from capital market frictions.

6 Conclusion

In this paper I treat frictions in the labor and capital market as a possible source of future productivity improvements via learning mechanisms. Using a novel approach, I find that increases in labor market frictions positively affect the future productivity of firms. This is in line with the idea that during periods of increased rigidities in the labor market firms face higher costs for adjusting labor (i.e reduced probability of adjusting labor). Therefore, they are forced to find alternative channels to substitute the costly adjustment of labor in order to meet demand for their final output. Such channels include reorganising their structures and improving management practices. Overall the increase in future productivity of firms comes from the more efficient use of intangible inputs due to the slow or non-adjustment of tangible inputs i.e labor.

However, increases in capital market frictions do induce significant productivity effects but are less prevalent and strong than before. In periods of increased capital market frictions it is very costly for firms to replace or update their existing capital. Therefore, they have to come up with ways to reconfigure their existing capital in order to make their production processes more productive to meet demand. However, productivity improvements via this channel are less prevalent compared to the case of labor. This is reconciled with the less-flexible-to-adjust nature of capital (tangible fixed assets) compared to labor, especially in the manufacturing sector, where production lines face capacity constraints that can mainly be relaxed when firms undertake new investments (i.e new machineries or upgrade of production processes), while labor can be reorganised in a more flexible way by reassigning tasks or responsibilities and restructuring management hierarchies within the firm.

Overall, I find suggestive evidence that firms are able to exploit any possible flexibility in their structures (i.e reassigning tasks across the existing workforce) in order to substitute

[23] Since information for exporting status is limited only to HR and FR, I restrict our analysis to these two countries.

[24] In this case the average learning by exporting effect is 0.5% and it is considerably smaller compared to that estimated in the literature so far (De Loecker, 2013; Manjón et al., 2013; Fernandes and Isgut, 2015). The driving force for this discrepancy is that in most cases the production function estimation procedure followed does not correct for value-added bias Gandhi et al. (2013) as discussed in Merlevede and Theodorakopoulos (2016).

alternative choices (i.e, adjusting labor) that are relatively more costly during certain periods. The higher the flexibility levels i.e, reassigning tasks across the existing workforce, the higher the future productivity effects. This effect is not uniform and is more prevalent in non-trading firms that are less likely to incur costs.

Concluding, the results should be considered as a special case from the broader set of mechanisms induced from input market frictions that could affect firm's efficiency. This is important to bare in mind when assessing policy reforms on the labor and capital market.

References

Abel, A. B. and J. C. Eberly (1994). A unified model of investment under uncertainty. *The American Economic Review 84*(5), 1369–1384.

Abel, A. B. and J. C. Eberly (1998). The mix and scale of factors with irreversibility and fixed costs of investment. In *Carnegie-Rochester Conference Series on Public Policy*, Volume 48, pp. 101–135. Elsevier.

Abowd, J. M. and F. Kramarz (2003). The costs of hiring and separations. *Labour Economics 10*(5), 499 – 530.

Ackerberg, D., K. Caves, and G. Frazer (2006). Structural estimation of production functions. *manuscript. Department of Economics, UCLA.*

Adda, J. and R. W. Cooper (2003). *Dynamic economics: quantitative methods and applications.* MIT press.

Aguirregabiria, V. and C. Alonso-Borrego (2014). Labor contracts and flexibility: Evidence from a labor market reform in spain. *Economic Inquiry 52*(2), 930–957.

Alvarez, F. and M. Veracierto (2001). Severance payments in an economy with frictions. *Journal of Monetary Economics 47*(3), 477 – 498.

Arrow, K. J. (1968). Optimal capital policy with irreversible investment. *Value, Capital and Growth*, 1–20.

Asphjell, M. K., W. Letterie, Ø. A. Nilsen, and G. A. Pfann (2014). Sequentiality versus simultaneity: Interrelated factor demand. *Review of Economics and Statistics 96*(5), 986–998.

Autor, D. H., W. R. Kerr, and A. D. Kugler (2007). Does employment protection reduce productivity? evidence from us states*. *The Economic Journal 117*(521), F189–F217.

Aw, B. Y., M. J. Roberts, and D. Y. Xu (2008). R&d investments, exporting, and the evolution of firm productivity. *American Economic Review 98*(2), 451–56.

Bertola, G. and R. J. Caballero (1990). Kinked adjustment costs and aggregate dynamics. In *NBER Macroeconomics Annual 1990, Volume 5*, pp. 237–296. MIT Press.

Bertola, G. and R. J. Caballero (1994). Irreversibility and aggregate investment. *The Review of Economic Studies 61*(2), 223–246.

Billor, N., A. S. Hadi, and P. F. Velleman (2000). Bacon: blocked adaptive computationally efficient outlier nominators. *Computational Statistics & Data Analysis 34*(3), 279 – 298.

Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica 77*(3), 623–685.

Bond, S. and J. Van Reenen (2007). Chapter 65 microeconometric models of investment and employment. Volume 6, Part A of *Handbook of Econometrics*, pp. 4417 – 4498. Elsevier.

Bureau van Dijk Electronic Publishing (2011). Amadeus database. `http://www.bvdinfo.com/en-us/our-products/company-information/international/amadeus`.

Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *American Economic Review 101*(1), 304–40.

Caballero, R. J. (1999). Aggregate investment. *Handbook of macroeconomics 1*, 813–862.

Caballero, R. J., K. N. Cowan, E. M. Engel, and A. Micco (2013). Effective labor regulation and microeconomic flexibility. *Journal of Development Economics 101*, 92 – 104.

Caballero, R. J. and E. M. R. A. Engel (1993). Microeconomic adjustment hazards and aggregate dynamics. *The Quarterly Journal of Economics 108*(2), 359–383.

Caballero, R. J. and E. M. R. A. Engel (1999). Explaining investment dynamics in u.s. manufacturing: A generalized (s, s) approach. *Econometrica 67*(4), 783–826.

Caballero, R. J., E. M. R. A. Engel, J. C. Haltiwanger, M. Woodford, and R. E. Hall (1995). Plant-level adjustment and aggregate investment dynamics. *Brookings Papers on Economic Activity 1995*(2), 1–54.

Caballero, R. J., E. M. R. A. Engel, and H. John (1997). Aggregate employment dynamics: Building from microeconomic evidence. *The American Economic Review 87*(1), 115–137.

Caballero, R. J. and J. V. Leahy (1996). Fixed costs: The demise of marginal q.

Card, D., J. Heining, and P. Kline (2012). Workplace heterogeneity and the rise of west german wage inequality.

Chen, X., Z. Liao, and Y. Sun (2014). Sieve inference on possibly misspecified semi-nonparametric time series models. *Journal of Econometrics 178, Part 3*, 639 – 658.

Chen, X. and D. Pouzo (2015). Sieve wald and qlr inferences on semi/nonparametric conditional moment models. *Econometrica 83*(3), 1013–1079.

Coşar, A. K., N. Guner, and J. Tybout (2016, March). Firm dynamics, job turnover, and wage distributions in an open economy. *American Economic Review 106*(3), 625–63.

Contreras, J. (2008). An empirical model of factor adjustment dynamics.

Cooper, R. and J. Haltiwanger (1993). The aggregate implications of machine replacement: Theory and evidence. *The American Economic Review 83*(3), 360–382.

Cooper, R., J. Haltiwanger, and L. Power (1999, September). Machine replacement and the business cycle: Lumps and bumps. *American Economic Review 89*(4), 921–946.

Cooper, R., J. Haltiwanger, and J. L. Willis (2007). Search frictions: Matching aggregate and establishment observations. *Journal of Monetary Economics 54, Supplement*, 56 – 78. Supplement issue: October 20-21 2006 Research Conference on 'Microeconomic Adjustment and Macroeconomic Dynamics' Sponsored by the Swiss National Bank (http://www.snb.ch) and Study Center Gerzensee (www.szgerzensee.ch).

Cooper, R., J. Haltiwanger, and J. L. Willis (2015). Dynamics of labor demand: Evidence from plant-level observations and aggregate implications. *Research in Economics 69*(1), 37 – 50.

Cooper, R. and J. L. Willis (2004). A comment on the economics of labor adjustment: Mind the gap: Rejoinder. *The American Economic Review 94*(4), 1245–1247.

Cooper, R. and J. L. Willis (2009). The cost of labor adjustment: Inferences from the gap. *Review of Economic Dynamics 12*(4), 632 – 647.

Cooper, R. W. and J. C. Haltiwanger (2006). On the nature of capital adjustment costs. *The Review of Economic Studies 73*(3), 611–633.

Davis, S. J. and J. Haltiwanger (1992). Gross job creation, gross job destruction, and employment reallocation. *The Quarterly Journal of Economics 107*(3), 819–863.

Davis, S. J., J. C. Haltiwanger, and S. Schuh (1998). Job creation and destruction. *MIT Press Books 1.*

De Loecker, J. (2013, August). Detecting learning by exporting. *American Economic Journal: Microeconomics 5*(3), 1–21.

De Loecker, J. and P. K. Goldberg (2014). Firm performance in a global market. *Annual Review of Economics 6*(1), 201–227.

De Loecker, J. and F. Warzynski (2012, May). Markups and firm-level export status. *American Economic Review 102*(6), 2437–71.

Dixit, A. (1992). Investment and hysteresis. *The Journal of Economic Perspectives 6*(1), 107–132.

Dixit, A. K. and R. S. Pindyck (1994). *Investment under uncertainty.* Princeton university press.

Dobbelaere, S. and M. Vancauteren (2014). Market imperfections, skills and total factor productivity: Firm-level evidence on belgium and the netherlands. *NBB Working Paper Series* (267).

Doms, M. and T. Dunne (1998). Capital adjustment patterns in manufacturing plants. *Review of Economic Dynamics 1*(2), 409 – 429.

Doraszelski, U. and J. Jaumandreu (2013). R&d and productivity: Estimating endogenous productivity. *The Review of Economic Studies*.

Doraszelski, U. and J. Jaumandreu (2014). Measuring the bias of technological change.

Dustmann, C., J. Ludsteck, and U. Schönberg (2009). Revisiting the german wage structure. *The Quarterly Journal of Economics 124*(2), 843–881.

Egger, H. and U. Kreickemeier (2009). Firm heterogeneity and the labor market effects of trade liberalization*. *International Economic Review 50*(1), 187–216.

Eslava, M., J. Haltiwanger, A. Kugler, and M. Kugler (2010). Factor adjustments after deregulation: panel evidence from colombian plants. *The Review of Economics and Statistics 92*(2), 378–391.

Fajgelbaum, P. D. (2013). Labor market frictions, firm growth, and international trade.

Felbermayr, G., J. Prat, and H.-J. Schmerer (2011). Globalization and labor market outcomes: Wage bargaining, search frictions, and firm heterogeneity. *Journal of Economic Theory 146*(1), 39 – 73.

Felbermayr, G. J., G. Impullitti, and J. Prat (2014). Firm dynamics and residual inequality in open economies.

Fernandes, A. M. and A. E. Isgut (2015). Learning-by-exporting effects: Are they for real? *Emerging Markets Finance and Trade 51*(1), 65–89.

Galeotti, M. and F. Schiantarelli (1991). Generalized q models for investment. *The Review of Economics and Statistics 73*(3), 383–392.

Gali, J., M. Gertler, and J. D. Lopez-Salido (2007). Markups, gaps, and the welfare costs of business fluctuations. *The review of economics and statistics 89*(1), 44–59.

Gandhi, A., S. Navarro, and D. Rivers (2013). On the identification of production functions: How heterogeneous is productivity?

Goldberger, A. S. (1968). The interpretation and estimation of cobb-douglas functions. *Econometrica 36*(3/4), 464–472.

Grossman, G. M. and E. Helpman (2002). Integration versus outsourcing in industry equilibrium. *The Quarterly Journal of Economics 117*(1), 85–120.

Grossman, G. M. and E. Helpman (2005). Outsourcing in a global economy. *The Review of Economic Studies 72*(1), 135–159.

Hall, R. E. (2004). Measuring factor adjustment costs. *The Quarterly Journal of Economics 119*(3), 899–927.

Hall, R. E. and D. W. Jorgenson (1969). Tax policy and investment behavior: Reply and further results. *The American Economic Review 59*(3), 388–401.

Hamermesh, D. S. (1989). Labor demand and the structure of adjustment costs. *The American Economic Review 79*(4), 674–689.

Hamermesh, D. S. (1996). *Labor Demand*. Princeton University Press.

Hamermesh, D. S. and G. A. Pfann (1996). Adjustment costs in factor demand. *Journal of Economic Literature 34*(3), 1264–1292.

Helpman, E. and O. Itskhoki (2010). Labour market rigidities, trade and unemployment. *The Review of Economic Studies 77*(3), 1100–1137.

Helpman, E., O. Itskhoki, M.-A. Muendler, and S. J. Redding (2016). Trade and inequality: From theory to estimation. *Review of Economic Studies*.

Helpman, E., O. Itskhoki, and S. Redding (2010a). Inequality and unemployment in a global economy. *Econometrica 78*(4), 1239–1283.

Helpman, E., O. Itskhoki, and S. Redding (2010b). Unequal effects of trade on workers with different abilities. *Journal of the European Economic Association 8*(2-3), 421–433.

Helpman, E., O. Itskhoki, and S. Redding (2011). Trade and labor market outcomes.

Hobijn, B. and A. Şahin (2013). Firms and flexibility. *Economic Inquiry 51*(1), 922–940.

Holt, C. C., F. Modigliani, J. F. Muth, and H. A. Simon (1960). Planning, production, inventories, and work force.

Hopenhayn, H. and R. Rogerson (1993). Job turnover and policy evaluation: A general equilibrium analysis. *Journal of Political Economy 101*(5), 915–938.

Javorcik, B. S. (2004). Does foreign direct investment increase the productivity of domestic firms? in search of spillovers through backward linkages. *The American Economic Review 94*(3), 605–627.

Klette, T. J. and Z. Griliches (1996). The inconsistency of common scale estimators when output prices are unobserved and endogenous. *Journal of Applied Econometrics 11*(4), 343–361.

Koeniger, W. and J. Prat (2007). Employment protection, product market regulation and firm selection. *The Economic Journal 117*(521), F302–F332.

Konings, J. and S. Vanormelingen (2015). The impact of training on productivity and wages: firm-level evidence. *Review of Economics and Statistics 97*(2), 485–497.

Kramarz, F. and M.-L. Michaud (2010). The shape of hiring and separation costs in france. *Labour Economics 17*(1), 27 – 37.

Lagos, R. (2006). A model of tfp. *The Review of Economic Studies 73*(4), 983–1007.

Lapatinas, A. (2012). On the interrelation of capital and labor adjustment costs at the firm level. *Studies in Nonlinear Dynamics & Econometrics 16*(3).

Letterie, W. A. and G. A. Pfann (2007). Structural identification of high and low investment regimes. *Journal of Monetary Economics 54*(3), 797 – 819.

Letterie, W. A., G. A. Pfann, and J. Polder (2004). Factor adjustment spikes and interrelation: an empirical investigation. *Economics Letters 85*(2), 145 – 150.

Levinsohn, J. and A. Petrin (2003). Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies 70*(2), 317–341.

Lucas, R. E. and E. C. Prescott (1971). Investment under uncertainty. *Econometrica 39*(5), 659–681.

Manjón, M., J. A. Máñez, M. E. Rochina-Barrachina, and J. A. Sanchis-Llopis (2013). Reconsidering learning by exporting. *Review of World Economics 149*(1), 5–22.

Merlevede, B., M. de Zwaan, K. Lenaerts, and V. Purice (2015). Multinational networks, domestic,and foreign firms in europe.

Merz, M. and E. Yashiv (2007). Labor and the market value of the firm. *The American Economic Review 97*(4), 1419–1431.

Nickell, S. (1974). On the role of expectations in the pure theory of investment. *The Review of Economic Studies 41*(1), 1–19.

Nilsen, i. and F. Schiantarelli (2000). Zeroes and lumps in investment: Empirical evidence on irreversibilities and non-convexities. (337.).

Nilsen, i. A., A. Raknerud, M. Rybalka, and T. Skjerpen (2009). Lumpy investments, factor adjustments, and labour productivity. *Oxford Economic Papers 61*(1), 104–127.

Nilsen, i. A., K. G. Salvanes, and F. Schiantarelli (2007). Employment changes, the structure of adjustment costs, and plant size. *European Economic Review 51*(3), 577 – 598.

OECD (Accessed on 22 July 2015). Dataset: Lfs - real minimum wages. `https://stats.oecd.org/Index.aspx?DataSetCode=RMW`.

Olley, G. S. and A. Pakes (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica 64*(6), 1263–1297.

Pakes, A. (1994). Dynamic structural models, problems and prospects: mixed continuous discrete controls and market interactions. In C. A. Sims (Ed.), *Advances in Econometrics*, Volume 2, pp. 171–274. Cambridge University Press. Cambridge Books Online.

Peck, S. C. (1974). Alternative investment models for firms in the electric utilities industry. *The Bell Journal of Economics and Management Science 5*(2), 420–458.

Petrin, A. and J. Sivadasan (2006). Job security does affect economic efficiency: Theory, a new statistic, and evidence from chile.

Petrin, A. and J. Sivadasan (2013). Estimating lost output from allocative inefficiency, with an application to chile and firing costs. *Review of Economics and Statistics 95*(1), 286–301.

Pindyck, R. S. (1991). Irreversibility, uncertainty, and investment. *Journal of Economic Literature 29*(3), 1110–1148.

Rota, P. (2004). Estimating labor demand with fixed costs. *International Economic Review 45*(1), 25–48.

Rothschild, M. (1971). On the cost of adjustment. *The Quarterly Journal of Economics 85*(4), 605–622.

Rust, J. (1987). Optimal replacement of gmc bus engines: An empirical model of harold zurcher. *Econometrica 55*(5), 999–1033.

Sakellaris, P. (2004). Patterns of plant adjustment. *Journal of Monetary Economics 51*(2), 425 – 450.

Servén, L. (1997). Irreversibility, uncertainty and private investment: Analytical issues and some lessons for africa. *Journal of African Economies 6*(3), 229–68.

Shapiro, M. D. (1986). The dynamic demand for capital and labor. *The Quarterly Journal of Economics 101*(3), 513–542.

Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking 1*(1), 15–29.

Wooldridge, J. M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters 104*(3), 112 – 114.

Appendices

A A Dynamic Model of Adjusting Factors

I introduce the structure of the economy and the assumptions needed. The model is in line with the estimation procedure that will be used in the next section. Any important deviation and expansion will be introduced vis-a-vis with the explanation.

A.1 Production Function

A single-product firm i at time t produces a nonstorable[25] output using the following production technology:

$$Q_{it}^S = F_{it}^S(K_{it}, L_{it}, M_{it}, \Omega_{it}) \tag{A.1}$$

where K_{it} is the capital level, L_{it} is the stock of homogeneous workers, M_{it} is the materials level, Ω_{it} is the firm's productivity and $F_{it}^S(\cdot)$ is the production technology used by firm i in period t.[26]

A.2 Demand

Firms face a downward sloping demand curve:

$$Q_{it}^D = F_{it}^D(P_{it}, \mathcal{X}_{it}) \tag{A.2}$$

where P_{it} is the output price level and $\mathcal{X}_{it}$ is a stochastic demand shock. Therefore, the inverse residual demand function $P_{it}(Y_{it}, \mathcal{X}_{it})$ will depend both on its output and the demand shifter respectively. By not imposing any further restrictions on consumer preferences, I allow for firm-time specific price elasticities of demand that in combination with various (static) price setting models allow for firm-time specific markups as in De Loecker and Warzynski (2012).

A.3 Revenue Function

With equilibrium in the output market, $Q_{it} = Q_{it}^S = Q_{it}^D$, I get the firm's revenue function:

$$R_{it}(A_{it}, K_{it}, L_{it}, M_{it}) = P_{it}(Q_{it}, \mathcal{X}_{it}) * Q_{it} \tag{A.3}$$

where $A_{it} = \{\mathcal{X}_{it}, \Omega_{it}\}$ includes both the shocks to demand and productivity respectively.[27]

A.4 Costs

Firms face two types of costs. First, is the direct cost of obtaining each input used in the production process:

$$DC_{it} = P_{it}^I I_{it} + P_{it}^L L_{it} + P_{it}^M M_{it} \tag{A.4}$$

[25] Both for simplicity and lack of data, I assume that inventories do not serve as a source of adjustment.

[26] The choice of inputs is an immediate outcome of the data in hand. The model can directly be extended to allow for hetereogeneity in employment (i.e. high-skilled vs low-skilled or temporary vs permanent workers), materials (i.e. outsourcing vs offshoring) and additional inputs (i.e. energy consumption and hours worked) as in Doraszelski and Jaumandreu (2014).

[27] In the special case of CES preferences, $Q_{it}^D = (\frac{P_{it}}{\mathcal{X}_{it}})^{\sigma}$, where the price elasticity of demand (σ) is constant for all firms, and under a Cobb-Douglas production function, $Q_{it}^S = {K_{it}}^{a_k} {L_{it}}^{a_l} {M_{it}}^{a_m} \Omega_{it}$, the revenue function boils down to $R_{it} = A_{it}({K_{it}}^{a_k} {L_{it}}^{a_l} {M_{it}}^{a_m})^{(1+\frac{1}{\sigma})}$, where $A_{it} = \mathcal{X}_{it} {\Omega_{it}}^{(1+\frac{1}{\sigma})}$ is revenue productivity as in Klette and Griliches (1996).

where P_{it}^{I} is the direct purchase price of new capital,[28] P_{it}^{L} is the wage offered to hire one unit of employment and P_{it}^{M} is the material price. All factor prices are exogenously set and known to the firm before any input decision is made in each period.

Second, is the cost of adjusting the non-freely variable inputs, in this case capital and labor:

$$C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}) = \begin{cases} C_{it}^{K}(A_{it}, K_{it}, K_{it+1}) & , if I_{it} \neq 0 \\ C_{it}^{L}(A_{it}, L_{it-1}, L_{it}) & , if \Delta L_{it} \neq 0 \\ C_{it}^{KL}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}) & , if \Delta L_{it} * I_{it} \neq 0 \end{cases} \tag{A.5}$$

where $C_{it}^{K}(\cdot)$ includes any possible type of convex costs embedded in the adjustment process of capital (invest, $I_{it} > 0$ or dinvest, $I_{it} < 0$). This includes installation costs (time and resources), learning of new technologies, disruption of productive activities, reallocation of resources, reassignment of tasks, reconfiguration of the production process, indivisibilities in capital, access to finance, changes in the extent of subsidies to new investment in capital equipment, etc.

The cost function $C_{it}^{L}(\cdot)$ captures all convex costs prevalent to the firm when adjusting labor (hiring, $\Delta L_{it} > 0$ or firing, $\Delta L_{it} < 0$). This includes severance pay, disruptions to production from reassignment of workers, search costs, training costs, fees to replacement agencies, mandatory advanced notice of layoffs, overhead cost of maintaining a human resource department, etc.

The component $C_{it}^{KL}(\cdot)$ captures any convex cost related to adjusting capital and labor simultaneously. This includes both prementioned costs from adjusting capital and labor separately but also costs incurred from adjusting them at the same time that could be positive (complementarities in simultaneous adjustment of capital and labor) or negative (cost advantage from sequential adjustment of each factor). For example, a firm may hire workers while investing in a new technology in order to install the new capital and bring it to full productivity faster than otherwise. However, some firms prefer to employ new workers and buy new machinery separately since the costs associated with new workers learning a new technology include higher fixed costs and longer adjustment periods than otherwise.

The adjustment cost function $C_{it}(\cdot)$ is firm-time specific, imposes no restrictions on the form of convex components and covers both the cases of simultaneous and sequential adjustment of capital and labor. Therefore, it includes any possible implicit and explicit cost that arises from both the environments in factor markets and government policies affecting the firm's path of optimal factor demand. Overall, instead of a particular model of adjustment costs, such as one based on search frictions (Cooper et al., 2007), I employ a more general approach that covers any possible type of adjustment costs but is agnostic with regards to the source of adjustment frictions.

It is important to mention here that the adjustment cost is treated as a function of K_{it}, K_{it+1}, since capital is a pre-determined dynamic input and L_{it-1}, L_{it}, since labor is a dynamic input but adjusts within the period. If I now assume time to adjust labor I just need to update the relevant components for the cost function to L_{it}, L_{it+1} since labor chosen today only becomes productive next period.

Combining all sources of costs for the firm, I get the following cost function:

$$TC_{it} = P_{it}^{I} I_{it} + P_{it}^{L} L_{it} + P_{it}^{M} M_{it} + C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}) \tag{A.6}$$

[28] I allow the price of capital to take values $P_{it}^{I} = \{P_{it}^{I^s}, P_{it}^{I^b}\}$, when the firm sells (dinvest) or buys (invest) capital respectively. This implies that capital is not fully reversible due to transactions costs, the physical costs of resale and the market for lemons phenomenon, consistent with the literature (Abel and Eberly, 1998; Sakellaris, 2004; Contreras, 2008) and also the observed distribution of capital adjustments in our data which is skewed to the left (see graph!!!!!). The main implications of irreversibility were originally analyzed by Arrow (1968); Lucas and Prescott (1971); Nickell (1974). More recent investment models with irreversibility include Bertola and Caballero (1990); Pindyck (1991); Dixit (1992); Abel and Eberly (1994); Bertola and Caballero (1994); Dixit and Pindyck (1994). For a review of the analytical and empirical literature on irreversible investment and evidence on its macro implications see Servén (1997).

A.5 A Note on Non-convex Adjustment Costs

Early attempts of the literature, employed standard neoclassical investment models with convex adjustment costs in order to understand aggregate investment activity (Hall and Jorgenson, 1969; Tobin, 1969). However, even at the aggregate level, such models have not performed well (Caballero, 1999). Aggregate statistics mask important underlying dynamics, since they smooth over various types of capital accumulation patterns across plants. A growing number of firm-level studies suggest a non-smooth adjustment path for the capital stock due to the intermittent and lumpy nature of investment.[29] Such studies emphasize the importance of non-convex adjustment costs on understanding the dynamics of capital adjustment.[30]

In the same spirit, although aggregate series are smooth, employment adjustment at the plant-level is extremely lumpy (Hamermesh, 1989; Davis and Haltiwanger, 1992). Labor adjustment distribution has fat tails, mix of small and large adjustments and a mass point around the inaction region.[31] Strand of the literature has focused on non-convex adjustment costs as a source of this heterogeneity. More specifically, they focus on the importance of non-convexities in adjustment costs for explaining plant level observations.[32] Their findings indicate that non-convex adjustment costs are critical for explaining plant-level observations on hours and employment adjustment and also necessary to explain aggregate behavior (Cooper and Willis, 2004, 2009).[33]

In the prementioned literature, all cases examined the adjustment of one quasi-fixed production factor alone. However, recent empirical evidence show that firms adjust along several margins and that the dynamics of capital and labor demand are interrelated.[34] The results indicate that models with fully specified interrelated non-convex adjustment cost structures outperform all other specifications.[35] Therefore, it is imperative to include the additional costs from adjusting factors simultaneously.

However, in this case I consider convex adjustment costs that will lead to analytical solutions. In order to accommodate the possibility of periods of non-adjustment and abstract from non-convexities in the adjustment cost function I can directly extend the model by pushing the optimal programme forward until the firm adjusts again, as in Pakes (1994). For an application on a model with only firing costs see Petrin and Sivadasan (2006).

A.6 Profit Function

Subtracting costs from revenues, I compute the firm's profit function:

$$\begin{aligned}\Pi_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}, M_{it}) =& R_{it}(A_{it}, K_{it}, L_{it}, M_{it}) - P^I_{it} I_{it} - P^L_{it} L_{it} - P^M_{it} M_{it} \\ &- C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it})\end{aligned} \tag{A.7}$$

[29]See Caballero et al. (1995); Doms and Dunne (1998); Nilsen and Schiantarelli (2000); Sakellaris (2004).

[30]Seminal contributions on the non-convex nature of adjustment costs include the discussion of Rothschild (1971) and evidence from industry case studies for specific technologies by Holt et al. (1960) and Peck (1974). Note that the theoretical literature had always been well ahead of its empirical counterpart on how to accommodate these issues, but access to firm-level data allowed for simultaneous evolution on this topic. Relevant studies include Rust (1987); Cooper and Haltiwanger (1993); Abel and Eberly (1994); Caballero et al. (1995); Caballero and Leahy (1996); Cooper et al. (1999); Caballero and Engel (1999); Cooper and Haltiwanger (2006); Letterie and Pfann (2007). For a review of such models see Adda and Cooper (2003); Bond and Van Reenen (2007).

[31]For micro-level studies on patterns of labor adjustment, see Hamermesh (1989); Davis and Haltiwanger (1992); Caballero et al. (1995, 1997); Davis et al. (1998).

[32]See Hamermesh (1989); Caballero and Engel (1993); Caballero et al. (1997); Aguirregabiria and Alonso-Borrego (2014); Cooper et al. (2015).

[33]For a lengthy discussion on models of labor adjustment see Hamermesh (1996); Bond and Van Reenen (2007) and for detailed research on the nature of labor adjustment costs see Hamermesh and Pfann (1996); Abowd and Kramarz (2003); Rota (2004); Nilsen et al. (2007); Kramarz and Michaud (2010).

[34]For non-structural approaches using micro-level data see Sakellaris (2004); Letterie et al. (2004); Nilsen et al. (2009). For models with joint adjustment of capital and labor see Shapiro (1986); Galeotti and Schiantarelli (1991); Abel and Eberly (1998); Hall (2004); Merz and Yashiv (2007); Bloom (2009).

[35]See Contreras (2008); Lapatinas (2012); Asphjell et al. (2014).

A.7 Adjustment and Timing of Inputs

Capital is a dynamic input that is quasi-fixed, since the choice for new capital is made in the previous period $t-1$ while it only becomes productive in period t (time to adjust new capital) and it faces adjustment costs.[36] Capital accumulates, with probability one, according to $K_{it} = (1-\delta_{it})K_{it-1} + I_{it-1}$, where δ_{it} is the rate of capital depreciation and I_{it-1} is the investment in new capital.

Labor is also a dynamic input but more flexible than capital, since it is both chosen and becomes productive within period t (no whole period to adjust labor) but also faces adjustment costs.[37] Labor evolves, with probability one, according to the law of motion $L_{it} = L_{it-1} + \Delta L_{it}$, where ΔL_{it} refers to the net changes in employment.[38]

Materials is a static (i.e., freely adjustable or variable) input since it faces no adjustment costs or period lag.[39]

A.8 Firm's Decision Problem

Firms decide the optimal demand for factors to be used in the production process.[40] This involves the choice for accumulation of capital (choosing I_{it} is equivalent to choosing K_{it+1}), hiring/firing labor and purchase of material inputs.[41]

The firm makes its decisions in a discrete time setting in order to maximize the expected net present value of future cash flows. The Bellman equation of the firm's dynamic programming problem is:

$$\begin{aligned} V_{it}(S_{it}) &= \max_{K_{it+1},L_{it},M_{it}} \{\Pi_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}, M_{it}) + \beta E[V_{it+1}(S_{it+1})|J_{it}]\} \\ &= \max_{K_{it+1},L_{it},M_{it}} \{R_{it}(A_{it}, K_{it}, L_{it}, M_{it}) - P^I_{it} I_{it} - P^L_{it} L_{it} - P^M_{it} M_{it} \\ &\qquad - C_{it}(A_{it}, K_{it}, K_{it+1}, L_{it-1}, L_{it}) + \beta E[V_{it+1}(S_{it+1})|J_{it}]\} \end{aligned} \tag{A.8}$$

where $V_{it}(\cdot)$ denotes the maximised value for firm i in period t, $S_{it} = \{A_{it}, K_{it}, L_{it-1}\}$ is the vector of state variables, β is the discount factor and $E[\cdot]$ denotes the expected value conditional on information available in period t (J_{it}). The expectation is taken over the distribution of profitability shocks. [42]

[36] Adjustment costs inherently capture the costs associated with the time to adjust new capital i.e, disruption of production.

[37] This assumption represents the fact that it is easier and it takes less time to adjust labor compared to capital. However, there are countries or markets where firms face a very stringent labor market and regulatory environment and therefore need a period to adjust their labor, as considered in Konings and Vanormelingen (2015). For an extensive discussion of various cases on the timing of factors see Ackerberg et al. (2006).

[38] I inherently assume that there are no simultaneous hiring and firing decisions i.e, gross changes. This translates to hiring when $\Delta L_{it} > 0$ and firing when $\Delta L_{it} < 0$. Also, without loss of generality the quit rate for employment is assumed zero due to data restrictions. Then main reason is that I interested in the average behavior of labor and I do not have access to such detailed data. For a detailed discussion on gross and net changes in employment see Hamermesh and Pfann (1996).

[39] Materials can be further split between in-house production and outsourced/offshored materials in order to account for contractual relationships between suppliers and firms (Grossman and Helpman, 2002, 2005) that will generate possible adjustment costs as in Doraszelski and Jaumandreu (2014).

[40] I implicitly assume that decisions are made by managers and there are no incentive problems between the manager and the owners of the firm. Therefore, managers always maximise the value of the plant in order to make optimal decisions.

[41] Without any loss of generality the model can be extended to any type of factor that the firm owns, hires, rents or purchases in order to accommodate the production process in each period.

[42] The uncertainty about the future arises because A_{it} evolves probabilistically. I assume that the profitability shocks evolve probabilistically following a first order Markov process. Note that I allow the distribution of future productivity to be dependent not only on current productivity but also on other possible factors such as tightness in the labor or capital market, exporting status etc that will later on be key components of our estimation strategy.

In the case of a static input i.e, materials the model boils down to a static optimization problem since there is no forward looking behaviour. At an interior solution, conditional on the choice of dynamic inputs, the static first order condition (FOC) for materials is:

$$\theta_{it}^{M}\frac{P_{it}Q_{it}}{M_{it}}\left(1-\frac{1}{\eta_{it}}\right)-P_{it}^{M}=0 \tag{A.9}$$

where $\theta_{it}^{M}=\frac{\partial Q_{it}}{\partial M_{it}}\frac{M_{it}}{Q_{it}}$ is the output elasticity of materials and $\eta_{it}=\left|\frac{\partial Q_{it}}{\partial P_{it}}\frac{P_{it}}{Q_{it}}\right|$ is the absolute value of the price elasticity of the residual demand for firm i in period t.[43] In this case the marginal revenue product of the static input is equated with its marginal cost.

A.8.1 No Adjustment Costs

In order to understand the contribution of adjustment costs I will start from the benchmark case where adjustment costs are absent i.e, $C_{it}(A_{it},K_{it},K_{it+1},L_{it-1},L_{it})\equiv 0$ for all $(A_{it},K_{it},K_{it+1},L_{it-1},L_{it})$. Note that there is still time to adjust aspect of capital, so the accumulation of capital remains forward looking. The FOC for capital combined with the respective envelope condition gives:

$$\beta E\Big[\theta_{it+1}^{K}\frac{P_{it+1}Q_{it+1}}{K_{it+1}}\left(1-\frac{1}{\eta_{it+1}}\right)+(1-\delta_{it})P_{it+1}^{I}\Big]-P_{it}^{I}=0 \tag{A.10}$$

where $\theta_{it+1}^{K}=\frac{\partial Q_{it+1}}{\partial K_{it+1}}\frac{K_{it+1}}{Q_{it+1}}$ is the output elasticity of capital for firm i in period $t+1$. The expected marginal return on capital is equated with the cost of an additional unit of capital today. The first term in expectation refers to the marginal profits from capital and the second term captures the resale value of non-depreciated capital at the next period's price (P_{it+1}^{I}).

Similar to the case of materials, the FOC for labor will come from the static per-period maximisation solution:

$$\theta_{it}^{L}\frac{P_{it}Q_{it}}{L_{it}}\left(1-\frac{1}{\eta_{it}}\right)-P_{it}^{L}=0 \tag{A.11}$$

where $\theta_{it}^{L}=\frac{\partial Q_{it}}{\partial L_{it}}\frac{L_{it}}{Q_{it}}$ is the output elasticity of labor for firm i in period $t+1$.[44]

A.8.2 With Adjustment Costs for Capital and Labor

The FOC for capital combined with the relevant envelope condition gives:

$$\begin{aligned}\beta E\Big[\theta_{it+1}^{K}\frac{P_{it+1}Q_{it+1}}{K_{it+1}}\left(1-\frac{1}{\eta_{it+1}}\right)+(1-\delta_{it})P_{it+1}^{I}\Big]-P_{it}^{I}\leq{}&\frac{\partial C_{it}(A_{it},K_{it},K_{it+1},L_{it-1},L_{it})}{\partial K_{it+1}}\\&+\beta E\Big[\frac{\partial C_{it+1}(A_{it+1},K_{it+1},K_{it+2},L_{it},L_{it+1})}{\partial K_{it+1}}\Big]\end{aligned} \tag{A.12}$$

where the first component of the right hand side is the marginal cost of adjusting new capital and the second component is the cost advantage on adjusting capital tomorrow from adjusting capital today. Therefore, the right hand side captures the contribution of the adjustment costs on optimal investment policy. It is clear that the presence of adjustment costs generates a

[43] Note that the markup of firm i at time t is captured by $\mu_{it}=\frac{\eta_{it}}{\eta_{it}-1}$. In the limit case of perfect competition where products are perfect substitutes, $\eta_{it}\to\infty$ and therefore $\mu_{it}=1$.

[44] In the case of time to adjust labor, the firm has to choose today the labor that will become productive next period (L_{it+1}). Therefore, the FOC becomes $\beta E\Big[\theta_{it+1}^{L}\frac{P_{it+1}Q_{it+1}}{L_{it+1}}\left(1-\frac{1}{\eta_{it+1}}\right)-P_{it+1}^{L}\Big]=0$. This is similar to the expression for capital (A.10), but without the extra term on the right hand side, since labor is hired every period and is not like capital that is accounted by the firm as a cumulative asset that depreciates and can be liquidated next period.

wedge between the expected marginal revenue product and the marginal cost of new capital. Alternatively, it can be seen as the difference between the direct and shadow price of capital.

Similarly, for the case of labor:

$$\theta^L_{it}\frac{P_{it}Q_{it}}{L_{it}}\left(1-\frac{1}{\eta_{it}}\right)-P^L_{it}\leq\frac{\partial C_{it}(A_{it},K_{it},K_{it+1},L_{it-1},L_{it})}{\partial L_{it}}+\beta E\Big[\frac{\partial C_{it+1}(A_{it+1},K_{it+1},K_{it+2},L_{it},L_{it+1})}{\partial L_{it}}\Big] \tag{A.13}$$

where the right hand side captures the marginal costs of adjusting labor. As before, the costs for adjusting labor drive a wedge between the marginal revenue product and marginal cost of labor. Equivalently this wedge is the difference between the wage of workers and their shadow wage.[45]

Both expressions hold with inequality because of the possibility of corner solutions i.e., non-adjusting firms. On the one hand, when firms adjust both capital and labor, expressions hold with equality.[46] [47] On the other hand, when at least one of the factors does not adjust, expressions hold with inequality. The inequality shows that at any other attainable level of the factor that is not adjusted, the marginal cost of adjusting is not equal to the marginal benefit.[48]

Overall, I see in both expressions that adjustment costs drive a wedge between the marginal revenue product and marginal costs of the non-freely adjustable inputs. Compared to the cases of no adjustment costs ,(A.10) and (A.11), this wedge is represented in the right hand side of (A.12) and (A.13).[49] In this case, the wedge captures any possible friction in labor and capital markets that do not allow firms to freely adjust their factors.

A.8.3 Measures of Capital and Labor Market Frictions

Given that I do not know the exact nature of adjustment costs and therefore their functional form, I cannot estimate this wedge from the right hand-side of expressions (A.12) and (A.13). However, from the left hand side I can express this wedge as a function of variables retrieved from the data and parameters to be estimated. It is important to mention that in the case of firms not adjusting at least one of the non-freely variable factors, these effects will be captured at a lower bound ($\leq$).

From rearranging (A.12), I express frictions in the capital market as 'experienced' by firm i in period t (henceforth KMF):

$$KMF_{it}(\theta^K_{it},\beta,\delta_{it})=\left|\theta^K_{it}\frac{P_{it}Q_{it}}{P^I_{it}K_{it}}\left(1-\frac{1}{\eta_{it}}\right)+(1-\delta_{it})-\frac{P^I_{it-1}}{\beta P^I_{it}}\right| \tag{A.14}$$

[45]In the case of time to adjust labor, (A.13) becomes $\beta E\Big[\theta^L_{it+1}\frac{P_{it+1}Q_{it+1}}{L_{it+1}}\left(1-\frac{1}{\eta_{it+1}}\right)-P^L_{it+1}\Big]\leq\frac{\partial C_{it}(A_{it},K_{it},K_{it+1},L_{it},L_{it+1})}{\partial L_{it+1}}+\beta E\Big[\frac{\partial C_{it+1}(A_{it+1},K_{it+1},K_{it+2},L_{it+1},L_{it+2})}{\partial L_{it+1}}\Big]$.

[46]This produces typical Euler equations (interior solutions) where factors adjust smoothly every period under the assumption of convex adjustment costs. This allows for analytically solvable models which in investment theory are labelled as Q-model. For a detailed overview see Adda and Cooper (2003); Bond and Van Reenen (2007).

[47]I can directly extend these expressions to accommodate the possibility of periods of non-adjustment by pushing the optimal programme forward until the firm adjusts again, as in Pakes (1994). For an application on a model with only firing costs see Petrin and Sivadasan (2006).

[48]This highly non-convex nature in the decision rules is generated by the introduction of adjustment costs allowing for simultaneous and sequential adjustment of capital and labor.

[49]This idea is not new in the literature. It is in line with the work of Petrin and Sivadasan (2006, 2013) that use the gap as a statistic to measure economic inefficiency from the presence of non-neoclassical components i.e., hiring, firing and search costs, capital adjustment costs, taxes and subsidies, hold-up and other contracting problems, non-optimal managerial behavior and markups. Also, it is conceptually similar to the seminal work of Caballero and Engel (1993) where they show that the gap between the observed and forecasted optimal level of employment is related to the probability of adjusting labor. For more on the gaps see Gali et al. (2007); Eslava et al. (2010); Caballero et al. (2013).

Because of the time to adjust aspect of capital, the firm will fully observe the benefits and costs from adjusting capital only in the period that the new capital becomes productive. This is because there are costs and benefits that evolve between the period that the new capital is chosen $(t-1)$ and the period it becomes productive (t). Since the choice for capital was made in the previous period, I also need to give a premium to the past period's values and thus divide all terms with the discount factor β. To control for the fact that the gap is measured in monetary values I divide (A.12) with P_{it}^{I}. This way, the expression represents the share of marginal costs of adjustment over the direct cost of new capital. The absolute value allows me to include in one measure both the cases of firms investing or disinvesting.[50] Overall, it is a uniteless measure of frictions in the capital market that is a function of variables retrieved from the data and parameters to be estimated or assumed from the literature.

From rearranging (A.13), I express frictions in labor market as 'experienced' by firm i in period t (henceforth LMF):

$$LMF_{it}(\theta_{it}^{L}) = \left| \theta_{it}^{L} \frac{P_{it}Q_{it}}{P_{it}^{L}L_{it}} \left(1 - \frac{1}{\eta_{it}}\right) - 1 \right| \tag{A.15}$$

Since labor adjusts within the period, the direct costs and benefits of labor are observed by the firm in this period. Similar to the case of capital, I express the gap as a share of the per-period average wage P_{it}^{L}.[51] The absolute value treats symmetrically the gaps from net hires and fires. Overall, it is a uniteless measure of frictions in the labor market that is expressed as a function of variables retrieved from the data and parameters to be estimated.

Overall, I have constructed a statistic that measures the presence of frictions in the labor and capital market. It is a uniteless measure specific to each firm-period and is expressed as a function of variables retrieved from the data and parameters to be estimated. It is an inherently relative measure that is interpreted as: firms with larger values of KMF_{it} (LMF_{it}) face relatively more frictions in the capital (labor) market i.e., more stringent.[52] As prementioned this measure includes all types of frictions that are present in the capital and labor market and also the way that each firm experiences them in each period.

[50] This implies that I inherently assume symmetry in the adjustment cost function for investing and disinvesting. Further heterogeneity can be uncovered by allowing asymmetry in the measures. However, I abstain from that since I are interested in the average behavior of the firm and specifically the Euclidean distance of the gap from 0. Also, it prevents the parameter space of our estimation routine from growing exponentially and resulting in a computationally intensive estimation.

[51] In the case of time to adjust labor, (A.15) remains the same but is generated from the expression in footnote 45, following the same steps as in the case of capital.

[52] Petrin and Sivadasan (2006, 2013) consider a similar measure of economic inefficiency for the special case of firing costs but keep it in monetary units.

B GNR Two-step Estimation Procedure

This section describes the steps and assumptions needed to estimate the effects of labor and capital market frictions on future productivity within a GNR two-step production function estimation procedure. For an in-depth analysis of the production function estimation procedure refer to Gandhi et al. (2013).

This case considers the classic environment of perfect competition in both input and output markets. Capital is a quasi-fixed input and therefore chosen one period prior to the realisation of productivity $(t-1)$. Rigidities in the labor market, induce high labor adjustment costs but firms still adjust their labor within the period. Therefore, labor is a dynamic input but more flexible than capital since it is chosen during the productivity realisation.[53] The only flexible input in our specification is material, assumed to freely adjust in each period (variable) and have no dynamic implications (static).

Conditional on the state variables and other firm characteristics, firm's static profit maximisation problem yields the first order condition with respect to the flexible input, material:[54]

$$P_t^M = P_t \frac{\partial}{\partial M_{it}} F(K_{it}, L_{it}, M_{it}) \mathrm{e}^{\omega_{it}} \mathcal{E} \tag{B.1}$$

where P_t^M and P_t is the price of material and output respectively. Under perfect competition in input and output markets, they are constant across firms within the same industry but can vary across time. By the time firms make their periodic decisions, ex-post shock ϵ_{it} is not in their information set. Hence, firms create expectations over it that are similar across firms, $\mathcal{E} = E(\mathrm{e}^{\epsilon_{it}})$.[55] It is important to account and correct for this term since ignoring it i.e., $\mathcal{E} = 1$, inherently implies that I move from the mean to the median central tendency of $\mathrm{e}^{\epsilon_{it}}$ (see Goldberger (1968)).

Combining (B.1) with production function (8) and re-arranging terms, I retrieve a share equation:

$$s_{it} = ln\ G(K_{it}, L_{it}, M_{it}) + ln\mathcal{E} - \epsilon_{it} \tag{B.2}$$

where s_{it} is the log of the nominal share of intermediate inputs and $G(K_{it}, L_{it}, M_{it}) = \frac{\partial lnF^S(K_{it}, L_{it}, M_{it})}{\partial lnM_{it}}$ is the output elasticity of the flexible input, material. Note that the share equation is net of the productivity term ω_{it}, inducing the transmission bias.

B.1 Step One

A Non Linear Least Squares (NLLS) estimation of the share equation (B.2) is applied, with:

$$G(L_{it}, K_{it}, M_{it})\mathcal{E} = \sum_{r_k + r_l + r_m \leq r} \gamma'_{r_k, r_l, r_m} k_{it}^{r_k} l_{it}^{r_l} m_{it}^{r_m},\ with\ \ r_k, r_l, r_m \geq 0 \tag{B.3}$$

approximated by a polynomial series estimator of order r. From this optimisation routine I identify $\widehat{\epsilon}_{it}$ (hence $\widehat{\mathcal{E}}$) and the parameters $\widehat{\gamma'}_{r_k, r_l, r_m}$. I proceed by recovering $\widehat{\gamma}_{r_k, r_l, r_m} \equiv \frac{\widehat{\gamma'}_{r_k, r_l, r_m}}{\widehat{\mathcal{E}}}$, $\forall\ r_k, r_l, r_m$ and then compute the output elasticity of the flexible input material $\widehat{G}(\cdot)$.[56]

---

[53] In the robustness section I consider alternative definitions of adjustment frictions i.e., time to adjust labor, to account for differences in the institutional environments across the various countries considered in the dataset.

[54] To improve efficiency of the estimation, I restrict the production function to vary only at the estimation level (industry/sector), and not over time. I assume that at the estimation level j (industry/sector), all firms have the same production technology $F^S(\cdot)$ but their output elasticities of inputs and factor shares can vary across firms and time. This is an immediate outcome of the estimation procedure that I employ.

[55] I inherently assume that the existence of any measurement error is symmetric across firms and thus does not affect our results. I would like to thank David Rivers for pointing this out.

[56] For the estimations I employ a polynomial of order $r = 2$, $\widehat{G}(\cdot) = \widehat{\gamma}_0 + \widehat{\gamma}_k k_{it} + \widehat{\gamma}_l l_{it} + \widehat{\gamma}_m m_{it} + \widehat{\gamma}_{kk} k_{it}^2 + \widehat{\gamma}_{ll} l_{it}^2 + \widehat{\gamma}_{mm} m_{it}^2 + \widehat{\gamma}_{kl} k_{it} l_{it} + \widehat{\gamma}_{km} k_{it} m_{it} + \widehat{\gamma}_{lm} l_{it} m_{it} + \widehat{\gamma}_{klm} k_{it} l_{it} m_{it}$. Note that I also include the triplet of capital, labor

B.2 Step Two

By integrating up the output elasticity of the flexible input:

$$\int \frac{G(K_{it}, L_{it}, M_{it})}{M_{it}} dM_{it} = lnF(K_{it}, L_{it}, M_{it}) + \mathcal{B}(K_{it}, L_{it}) \tag{B.4}$$

I nonparametrically identify the production function up to an unknown constant of integration.[57] By differencing it with the production function (??) I retrieve the following equation for productivity:

$$\omega_{it} = \mathcal{Y}_{it} + \mathcal{B}(K_{it}, L_{it}) \tag{B.5}$$

where $\mathcal{Y}_{it}$ is the log of the expected output net of the computed integral (B.4) and $\mathcal{B}(K_{it}, L_{it})$ is the constant of integration, approximated by a polynomial series estimator of degree ν:[58]

$$\mathcal{B}(K_{it}, L_{it}) = \sum_{\nu_k+\nu_l \leq \nu} \alpha_{\nu_k,\nu_l} k_{it}^{\nu_k} l_{it}^{\nu_l},\ with\ \ \nu_k, \nu_l > 0 \tag{B.6}$$

Therefore after the first stage, I can compute productivity:

$$\omega_{it}(\alpha) = \widehat{\mathcal{Y}}_{it} + \sum_{\nu_k+\nu_l \leq \nu} \alpha_{\nu_k,\nu_l} k_{it}^{\nu_k} l_{it}^{\nu_l},\ \forall\ \alpha = \{\alpha_{\nu_k,\nu_l} \forall \nu_k, \nu_l\} \tag{B.7}$$

To proceed, I exploit the assumption over the law of motion of productivity. Similar to the seminal work of Olley and Pakes (1996), an exogenous first order Markov process can be assumed, $\omega_{it} = g(\omega_{it-1}) + \xi_{it}$. However, exogeneity should be relaxed in order to accommodate the fact that productivity evolves endogenously in response to firms' actions (De Loecker, 2013; Doraszelski and Jaumandreu, 2013; De Loecker and Goldberg, 2014). I expect that actions undertaken by firms, in response to shocks, affect their productivity evolution. Such actions could be observed (R&D, exporting, FDI, investing, etc.) or not (firms replace current managers by better ones or adopt better management practices and these actions are not reflected in changes in expenditures) by the econometrician. Therefore, the law of motion for productivity should be modified so as to explicitly allow for these actions to affect productivity.[59]

On top of lagged productivity, lagged and observable decision variables for firm i in period t are also allowed to affect current productivity outcomes (in expectation):[60]

$$\omega_{it} = g(\omega_{it-1}, lnKMF_{it-1}, lnLMF_{it-1}, s_{it-1}) + \xi_{it} \tag{B.8}$$

where $lnKMF_{it-1}$, $lnLMF_{it-1}$ is the log of the measure of frictions in capital and labor markets respectively, s_{it-1} captures other relevant controls[61] and ξ_{it} denotes the productivity innovation.[62]

---

and materials to account for possible interactions between them. I abstain from using polynomials of higher order since estimation becomes computationally intensive but results are similar.

[57]Because of the selected polynomial sieve estimator chosen before, the integral has a closed-form solution: $\int \frac{G(K_{it},L_{it},M_{it})}{M_{it}} dM_{it} = \sum_{r_k+r_l+r_m \leq r} \frac{\gamma_{r_k,r_l,r_m}}{r_m+1} k_{it}^{r_k} l_{it}^{r_l} m_{it}^{r_m+1},\ with\ \ r_k, r_l, r_m \geq 0.$

[58]For the estimations I employ a polynomial of order $\nu = 2$, $\mathcal{B}(\cdot) = \alpha_k k_{it} + \alpha_l l_{it} + \alpha_{kk} k_{it}^2 + \alpha_{ll} l_{it}^2 + \alpha_{kl} k_{it} l_{it}$. I abstain from using polynomials of higher order since estimation becomes computationally intensive but results are similar.

[59]The fact that these actions are allowed to affect productivity does not mean that they will in fact do so. Hence the above formulation does not assume the result. An explicit model on how such actions are determined would ideally supplement this law of motion. Recent structural models include the cases of exporting and R&D by Aw et al. (2008) and of exporting and technology upgrade by Bustos (2011).

[60]By employing lagged values I inherently assume that it takes one period for actions to affect productivity.

[61]More specifically $s_{it-1} = (FE_{t-1}, FE_j, FE_r, FE_c)$ includes time, industry (if estimated at the sectoral level), nuts2-region (if estimated at the industry or sectoral level) and country (if estimated at the EU level) fixed effects respectively.

[62]For the estimations, I use both a linear ($\omega_{it} = \rho_\omega \omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + s_{it-1} + \xi_{it}$) and second order polynomial ($\omega_{it} = \rho_\omega \omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + \rho_{\omega\omega} \omega_{it-1}^2 + \rho_{\kappa\kappa} lnKMF_{it-1}^2 + \rho_{\lambda\lambda} lnLMF_{it-1}^2 + \rho_{\omega\kappa} \omega_{it-1} lnKMF_{it-1} + \rho_{\omega\lambda} \omega_{it-1} lnLMF_{it-1} + \rho_{\kappa\lambda} lnKMF_{it-1} lnLMF_{it-1} + \rho_{\omega\kappa\lambda} \omega_{it-1} lnKMF_{it-1} lnLMF_{it-1} + s_{it-1} + \xi_{it}$) approximation of $g(\cdot)$ with additive time fixed effects s_{it-1}. Fixed effects enter in an additive fashion in order to restrict the parameter space from exploding. I abstain from reporting polynomials of third order since results are similar and estimation becomes computationally intensive.

I can now express the innovation of productivity $\xi_{it}(\alpha)$ as a function of the parameters of the constant of integral, by non parametrically regressing $\omega_{it}(\alpha)$ on $g(\omega_{it-1}(\alpha), lnKMF_{it-1}(\alpha), lnKMF_{it-1}(\alpha), s_{it-1})$. The novelty of the approach is that as in the case of lagged productivity, the measures of capital and labor market frictions are expressed as functions of the parameters of the constant of integral, since their respective output elasticities are also functions of α's:

$$\begin{aligned}\theta_{it}^{K}(\alpha) &= \frac{\partial lnF(K_{it}, L_{it}, M_{it})}{\partial lnK_{it}} = \frac{\partial \int \frac{\widehat{G}(K_{it}, L_{it}, M_{it})}{M_{it}} dM_{it}}{\partial lnK_{it}} - \frac{\partial \mathcal{B}(K_{it}, L_{it})}{\partial lnK_{it}} \\ &= \sum_{r_k+r_l+r_m \leq r} \frac{\widehat{\gamma}_{r_k,r_l,r_m}}{r_m+1} r_k k_{it}^{r_k-1} l_{it}^{r_l} m_{it}^{r_m+1} - \sum_{\nu_k+\nu_l \leq \nu} \alpha_{\nu_k,\nu_l} \nu_k k_{it}^{\nu_k-1} l_{it}^{\nu_l}\end{aligned} \tag{B.9}$$

$$\begin{aligned}\theta_{it}^{L}(\alpha) &= \frac{\partial lnF(K_{it}, L_{it}, M_{it})}{\partial lnL_{it}} = \frac{\partial \int \frac{\widehat{G}(K_{it}, L_{it}, M_{it})}{M_{it}} dM_{it}}{\partial lnL_{it}} - \frac{\partial \mathcal{B}(K_{it}, L_{it})}{\partial lnL_{it}} \\ &= \sum_{r_k+r_l+r_m \leq r} \frac{\widehat{\gamma}_{r_k,r_l,r_m}}{r_m+1} r_l k_{it}^{r_k} l_{it}^{r_l-1} m_{it}^{r_m+1} - \sum_{\nu_k+\nu_l \leq \nu} \alpha_{\nu_k,\nu_l} \nu_l k_{it}^{\nu_k} l_{it}^{\nu_l-1}\end{aligned} \tag{B.10}$$

Specifically, the log of the measures of capital and labor market frictions employed in the estimations are expressed as:[63]

$$lnKMF_{it}(\alpha, \delta_j) = ln\left|\theta_{it}^{K}(\alpha)\frac{P_{it}\widehat{Y}_{it}}{P_{it}^{I}K_{it}} - \delta_j\right| \tag{B.11}$$

$$lnLMF_{it}(\alpha) = ln\left|\theta_{it}^{L}(\alpha)\frac{P_{it}\widehat{Y}_{it}}{P_{it}^{L}L_{it}} - 1\right| \tag{B.12}$$

where $\widehat{Y}_{it} = \frac{Y_{it}}{exp(\widehat{\epsilon}_{it})}$, is the observed output Y_{it} corrected for the ex post shocks $\widehat{\epsilon}_{it}$ estimated from the first step[64], $P_{it}^{I}K_{it}$ is tangible fixed assets, $P_{it}^{L}L_{it}$ is the cost of employees and $P_{it}Y_{it}$ is total sales.[65]

The second step proceeds with a standard GMM technique. The set of moments used are $E[\xi_{it}(\alpha) \otimes n_{it}'] = 0$, where $n_{it} = (k_{it}, l_{it-1}, k_{it}l_{it-1}, \cdots, k_{it}^{\nu_k} l_{it-1}^{\nu_l})\ \forall\ \nu_k, \nu_l > 0 \mid \nu_k + \nu_l \leq \nu$.[66] The orthogonality conditions, directly depend on the timing assumptions of inputs. Capital is assumed to be decided a period ahead and therefore orthogonal to the innovation in productivity. However, for labor I rely on lagged values since current labor is expected to react to shocks to productivity, and therefore $E[\xi_{it}(\alpha)l_{it}]$ is expected to be nonzero.[67] [68]

[63]For the estimations I employ a polynomial of order $r = 2$ for $G(\cdot)$ and $\nu = 2$ for $\mathcal{B}(\cdot)$. Hence, the respective output elasticities become: $\theta_{it}^{K}(\alpha) = (\widehat{\gamma}_k + 2\widehat{\gamma}_{kk}k_{it} + \widehat{\gamma}_{kl}l_{it} + \frac{\widehat{\gamma}_{km}}{2}m_{it} + \frac{\widehat{\gamma}_{klm}}{2}l_{it}m_{it})m_{it} - \alpha_k - 2\alpha_{kk}k_{it} - \alpha_{kl}l_{it}$ and $\theta_{it}^{L}(\alpha) = (\widehat{\gamma}_l + 2\widehat{\gamma}_{ll}l_{it} + \widehat{\gamma}_{kl}k_{it} + \frac{\widehat{\gamma}_{lm}}{2}m_{it} + \frac{\widehat{\gamma}_{klm}}{2}k_{it}m_{it})m_{it} - \alpha_l - 2\alpha_{ll}l_{it} - \alpha_{kl}k_{it}$.

[64]This correction is of great significance since potential inhomogeneities in the data could distort the magnitudes of the measures. Under the same concern, special attention is paid on how I trim the data and what method is employed.

[65]For both measures, since I assume that firms operate under perfect competition in the output market, $\eta_{it} \to \infty \Rightarrow \left(1 - \frac{1}{\eta_{it}}\right) = 1$. For the measure of capital market frictions, since I do not observe the direct price of investment P_{it}, I make the simplifying assumption that when the choice for capital is made, its price is approximately equal to its next period's discounted price i.e $P_{it-1}^{I} \approx \beta P_{it}^{I}$. Finally, the depreciation rate of capital δ_j is computed from the data as the total amount of depreciation and amortization of the assets over total assets. I use total instead of fixed assets since the numerator contains depreciation of both intangibles, other assets and amortization. To avoid outliers and missing values, I use the mean values across firms within each industry j.

[66]For the estimations I use a polynomial of degree $\nu = 2$ for $\mathcal{B}(\cdot)$ leading to $n_{it} = (k_{it}, l_{it-1}, k_{it}^2, l_{it-1}^2, k_{it}l_{it-1})$.

[67]In the case of time to adjust aspect of labor, the moment condition should include current instead of lagged labor. In order for lagged labor to be a valid instrument for current labor, however, I require input prices to be correlated over time. I find very strong evidence in favor of this by running various specifications that essentially relate current wages to past wages.

[68]Consistency and asymptotic normality of functionals of F (such as moments and productivity distribution) follow from Chen et al. (2014) and Chen and Pouzo (2015).

On the one hand, from this two-step procedure, I retrieve estimates of the production function coefficients that allow us to compute productivity $\hat{\omega_{it}}$ and other relevant variables i.e output elasticities of inputs and returns to scale for firm i at time t, using the following form of gross-output production function:[69]

$$y_{it} = \sum_{r_k+r_l+r_m \leq r} \frac{\widehat{\gamma}_{r_k,r_l,r_m}}{r_m+1} k_{it}^{r_k} l_{it}^{r_l} m_{it}^{r_m+1} - \sum_{\nu_k+\nu_l \leq \nu} \widehat{\alpha}_{\nu_k,\nu_l} k_{it}^{\nu_k} l_{it}^{\nu_l} + \omega_{it} + \widehat{\epsilon}_{it} \tag{B.13}$$

On the other hand, the effects on future productivity of firms from labor $\frac{\partial g(\cdot)}{\partial lnLMF_{it-1}}$ and capital $\frac{\partial g(\cdot)}{\partial lnKMF_{it-1}}$ market frictions can directly be estimated within the second step. This means that by exploiting the optimal decisions from the dynamic problem of a firm I can capture frictions in the capital and labor market as a function of parameters that can directly be identified within any typical semi-parametric model.

[69]For the estimations I employ a polynomial of order $r = 2$ for $G(\cdot)$ and $\nu = 2$ for $\mathcal{B}(\cdot)$. Hence, $y_{it} = (\gamma_0 + \gamma_k k_{it} + \gamma_l l_{it} + \frac{\gamma_m}{2} m_{it} + \gamma_{kk} k_{it}^2 + \gamma_{ll} l_{it}^2 + \frac{\gamma_{mm}}{3} m_{it}^2 + \gamma_{kl} k_{it} l_{it} + \frac{\gamma_{km}}{2} k_{it} m_{it} + \frac{\gamma_{lm}}{2} l_{it} m_{it} + \frac{\gamma_{klm}}{2} k_{it} l_{it} m_{it}) m_{it} - \alpha_l l_{it} - \alpha_k k_{it} - \alpha_{ll} l_{it}^2 - \alpha_{kk} k_{it}^2 + \alpha_{kl} k_{it} l_{it} + \omega_{it} + \epsilon_{it}$.

C Figures and Tables

Table 1: List of NACE 2-digit rev1.1 industries included in the data.

Broad category	NACE 2-digit	Description
DA	15	Manufacture of food products and beverages
DA	16	Manufacture of tobacco products
DB	17	Manufacture of textiles
DB	18	Manufacture of wearing apparel; dressing and dyeing of fur
DC	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
DD	20	Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
DE	21	Manufacture of pulp, paper and paper products
DE	22	Publishing, printing and reproduction of recorded media
DF	23	Manufacture of coke, refined petroleum products and nuclear fuel
DG	24	Manufacture of chemicals and chemical products
DH	25	Manufacture of rubber and plastic products
DI	26	Manufacture of other non-metallic mineral products
DJ	27	Manufacture of basic metals
DJ	28	Manufacture of fabricated metal products, exc. machinery/equipment
DK	29	Manufacture of machinery and equipment n.e.c.
DL	30	Manufacture of office machinery and computers
DL	31	Manufacture of electrical machinery and apparatus n.e.c.
DL	32	Manufacture of radio/television/communication equipment/apparatus
DL	33	Manufacture of medical/precision/optical instruments, watches/clocks
DM	34	Manufacture of motor vehicles, trailers and semi-trailers
DM	35	Manufacture of other transport equipment
DN	36	Manufacture of furniture; manufacturing n.e.c.
DN	37	Recycling

Table 2: Firm-level data

Country	Statistics	Operating Revenue	Tangible Fixed Assets	Number of Employees	Material Costs	Average Wage	Exporting Status	SUB 50%	SHH 50%
BE	Mean	57900	6579	133	38157	46234	.	.13	.15
	Sd	427306	29431	360	373743	18040	.	.33	.35
	Obs	23689	23689	23689	23689	23689	0	23689	23689
BG	Mean	5324	2412	164	3512	2305	.	.0012	.28
	Sd	56868	20883	499	50486	3137	.	.035	.45
	Obs	8297	8297	8297	8297	8297	0	8297	8297
CZ	Mean	13205	4030	148	8253	10538	0	.0049	.094
	Sd	84317	26427	457	62822	10288	.	.07	.29
	Obs	30528	30528	30528	30528	30528	1	30528	30528
DE	Mean	83516	13904	298	45469	48197	.	.091	.31
	Sd	245665	60317	748	141422	24660	.	.29	.46
	Obs	9886	9886	9886	9886	9886	0	9886	9886
EE	Mean	1612	486	39	978	6253	.2	.0023	.13
	Sd	4825	2104	108	3098	5009	.4	.048	.34
	Obs	12585	12585	12585	12585	12585	5628	12585	12585
ES	Mean	6741	1453	31	4272	23466	.	.0062	.019
	Sd	105343	16287	170	88292	14469	.	.078	.14
	Obs	332585	332585	332585	332585	332585	0	332585	332585
FI	Mean	8083	1985	40	4441	32278	.	.01	.017
	Sd	47542	17413	128	31025	11246	.	.1	.13
	Obs	24871	24871	24871	24871	24871	0	24871	24871
FR	Mean	13122	1572	57	6314	35305	.49	.014	.19
	Sd	85806	12647	241	49177	14936	.5	.12	.39
	Obs	203420	203420	203420	203420	203420	199008	203420	203420
HR	Mean	2577	1293	45	1700	7432	.39	.0042	.055
	Sd	16534	9639	183	10122	5332	.49	.064	.23
	Obs	8649	8649	8649	8649	8649	8600	8649	8649
IT	Mean	13449	2540	53	7332	32743	.	.018	.05
	Sd	91527	17067	182	65535	26368	.	.13	.22
	Obs	215722	215722	215722	215722	215722	0	215722	215722
NO	Mean	9644	1710	35	5616	43714	.	.0095	.038
	Sd	93316	19497	113	75084	19711	.	.097	.19
	Obs	28804	28804	28804	28804	28804	0	28804	28804
PL	Mean	15762	4196	176	9654	8836	.	.0016	.12
	Sd	69609	16590	325	50194	8495	.	.04	.32
	Obs	18379	18379	18379	18379	18379	0	18379	18379
RO	Mean	2231	795	118	1382	1850	.	.00086	.24
	Sd	25407	6836	334	19449	2423	.	.029	.43
	Obs	17522	17522	17522	17522	17522	0	17522	17522
SE	Mean	5597	1338	28	2341	26634	1	.014	.016
	Sd	36047	10680	99	22748	9427	0	.12	.13
	Obs	42747	42747	42747	42747	42747	14709	42747	42747
SI	Mean	5268	2059	58	2944	15291	.86	.0058	.0094
	Sd	23413	11034	188	10910	6894	.35	.076	.096
	Obs	10111	10111	10111	10111	10111	5354	10111	10111
SK	Mean	22421	8752	198	14425	18428	.	.0082	.018
	Sd	151855	69293	590	113377	29787	.	.09	.13
	Obs	4252	4252	4252	4252	4252	0	4252	4252

Notes: Firm-level data from Amadeus dataset for 146268 manufacturing firms from 16 EU countries during 1998 to 2007. Operating Revenue, Tangible Fixed Assets and Material are in thousand Euro.

Table 3: Productivity effects of Labor Market Frictions in EU

Industry	Linear	General - 2nd order			
	Mean	p(25)	Mean	Median	p(75)
15	0.003***	0.002***	0.005***	0.005***	0.008***
17	0.002*	-0.001	0.003***	0.004***	0.008***
18	-0.003	-0.012***	-0.006	-0.007	0.001
19	0.002	0.004	0.008	0.008	0.012***
20	0.004***	0.003***	0.005***	0.005***	0.006***
21	0.005***	0.003**	0.007***	0.007***	0.010***
22	0.009**	0.010	0.012**	0.013**	0.015***
24	0.009***	0.009***	0.012***	0.012***	0.015***
25	0.003	0.003***	0.005***	0.005***	0.006***
26	0.020***	0.003***	0.006***	0.006***	0.009***
27	0.002	-0.000	0.002	0.003	0.005
28	0.009	0.003	0.004	0.004	0.006
29	0.005***	0.004***	0.007***	0.007***	0.010***
31	0.004***	0.003***	0.007***	0.007***	0.010***
32	0.011***	0.006*	0.008***	0.008**	0.010***
33	0.007	0.004	0.008	0.008	0.011**
34	0.001	-0.000	0.001	0.002	0.003
35	0.002	-0.002	0.001	0.001	0.004
36	0.008***	0.007***	0.009***	0.010***	0.012***
37	0.013***	-0.003	0.006	0.006	0.016**

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Linear refers to the model $\omega_{it} = \rho_\omega \omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + s_{it-1} + \xi_{it}$ and General-2nd order refers to $\omega_{it} = \rho_\omega \omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + \rho_{\omega\omega}\omega^2_{it-1} + \rho_{\kappa\kappa} lnKMF^2_{it-1} + \rho_{\lambda\lambda} lnLMF^2_{it-1} + \rho_{\omega\kappa}\omega_{it-1} lnKMF_{it-1} + \rho_{\omega\lambda}\omega_{it-1} lnLMF_{it-1} + \rho_{\kappa\lambda} lnKMF_{it-1} lnLMF_{it-1} + \rho_{\omega\kappa\lambda}\omega_{it-1} lnKMF_{it-1} lnLMF_{it-1} + s_{it-1} + \xi_{it}$ which is a 2nd order polynomial approximation of $g(\cdot)$. Both specifications include additive year and country fixed effects. Table reports the marginal effects $\frac{\partial \omega_{it}}{\partial lnLMF_{it-1}}$ from each specification, estimated for each Nace 2-digit rev1.1 industry of the EU sample. For the latter specification I report different moments of the distribution of estimated effects. Standard errors are block-bootstrapped with 500 replications over the GNR two-step estimation procedure and are not reported for space considerations.

Table 4: Productivity effects of Capital Market Frictions in EU (in percent)

Industry	Linear	General - 2nd order			
	Mean	p(25)	Mean	Median	p(75)
15	0.004***	-0.002*	0.002	0.002*	0.005***
17	0.005***	-0.004**	0.005***	0.005***	0.014***
18	-0.005**	-0.021***	-0.012***	-0.012***	-0.002
19	0.001	0.002	0.006	0.007	0.011
20	0.008***	0.000	0.003*	0.004**	0.007***
21	0.003*	-0.001	0.002	0.002	0.005**
22	0.003***	0.001	0.001	0.001	0.002
24	0.011***	0.005**	0.007***	0.007***	0.010***
25	0.002**	-0.004***	-0.000	-0.001	0.003***
26	0.008***	-0.003	0.002	0.003*	0.009***
27	0.006***	-0.002	0.003	0.003	0.008
28	0.004***	0.002	0.003**	0.003***	0.004***
29	0.011	0.004***	0.008***	0.008***	0.012***
31	0.010	0.003	0.009***	0.009***	0.016***
32	0.002	-0.001	0.003	0.003	0.007**
33	0.007	0.000	0.004	0.004	0.007
34	0.006***	-0.001	0.003	0.004	0.008
35	0.005	-0.007**	-0.001	-0.001	0.005*
36	0.012***	0.004	0.009***	0.010***	0.014***
37	0.003	-0.003	0.000	-0.000	0.004

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Linear refers to the model $\omega_{it} = \rho_\omega \omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + s_{it-1} + \xi_{it}$ and General-2nd order refers to $\omega_{it} = \rho_\omega \omega_{it-1} + \rho_\kappa lnKMF_{it-1} + \rho_\lambda lnLMF_{it-1} + \rho_{\omega\omega}\omega^2_{it-1} + \rho_{\kappa\kappa} lnKMF^2_{it-1} + \rho_{\lambda\lambda} lnLMF^2_{it-1} + \rho_{\omega\kappa}\omega_{it-1} lnKMF_{it-1} + \rho_{\omega\lambda}\omega_{it-1} lnLMF_{it-1} + \rho_{\kappa\lambda} lnKMF_{it-1} lnLMF_{it-1} + \rho_{\omega\kappa\lambda}\omega_{it-1} lnKMF_{it-1} lnLMF_{it-1} + s_{it-1} + \xi_{it}$ which is a 2nd order polynomial approximation of $g(\cdot)$. Both specifications include additive year and country fixed effects. Table reports the marginal effects $\frac{\partial \omega_{it}}{\partial lnKMF_{it-1}}$ from each specification, estimated for each Nace 2-digit rev1.1 industry of the EU sample. For the latter specification I report different moments of the distribution of estimated effects. Standard errors are block-bootstrapped with 500 replications over the GNR two-step estimation procedure and are not reported for space considerations.

Table 5: Productivity effects from market frictions and trade in Croatia

	p(25)	Average	Median	p(75)
ω_{it-1}	0.753***	0.822***	0.822***	0.890***
	(0.019)	(0.014)	(0.019)	(0.027)
$lnLMF_{it-1}$	-0.001	0.007***	0.006***	0.012***
	(0.002)	(0.001)	(0.002)	(0.002)
$lnKMF_{it-1}$	-0.004***	-0.002**	-0.002**	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
EXP_{it-1}	-0.001	0.005*	0.008***	0.013***
	(0.003)	(0.003)	(0.003)	(0.004)
$lnLMF_{it-1} * EXP_{it-1}$	-0.009***	-0.005*	-0.006**	-0.002
	(0.003)	(0.003)	(0.003)	(0.003)
$lnKMF_{it-1} * EXP_{it-1}$	-0.003	-0.000	-0.001	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	7305	7305	7305	7305

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are given by the model $g(\omega_{it-1}, LMF_{it-1}, KMF_{it-1}, EXP_{it-1})$. I report different moments of the distribution of estimated results. All specifications include additive year, industry and region fixed effects. Standard errors are block-bootstrapped with 500 replications over the GNR two-step estimation procedure and are reported in parenthesis below point estimates.