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To What Extent Is the Low Interest Rate Environment Driving Labour Productivity Divergence between Euro Area Countries?

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Abstract

This paper studies the labour productivity divergence in the Euro Area by scrutinizing the link between the low interest rate environment, the widening productivity gap between periphery and core countries and the lower growth of the Monetary Union. It makes use of firm-level data to apply a mechanism rooted in the dynamic competition literature and to assess to what extent an unequal distribution of frontier and non-frontier firms across the Eurozone might be the reason why Southern countries are still lagging behind. The evidence presented suggests that low long-term interest rates might be enlarging their distance to the Euro frontier.

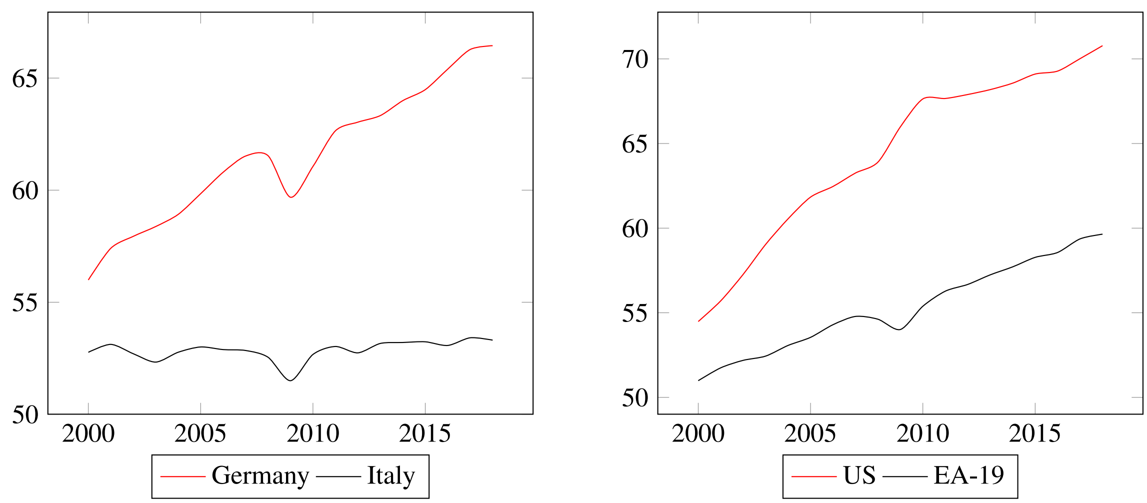
JEL Classification: E43, F15, J24, O52

Keywords: Productivity, Interest Rate, Euro Area, Divergence

1 Introduction

Since its beginning, the European Economic and Monetary Union has been marked by a divergence between labour productivity levels of core and periphery countries (Lains, 2019). Panel (a) of Figure 1 shows how the productivity gap between Germany and Italy, a core and a periphery country respectively, has increased since the Euro project took off. Furthermore, since the turning of the century, the lack of convergence within the Euro Area came along with a gradual worsening of the relative growth performance of the block as whole. As shown by panel (b) of the same figure, and as documented in the literature, Europeans have seen their productivity gap to the US enlarged in the last two decades (Buiatti et al., 2017).

Figure 1: GDP per hour worked: US 2010 dollars, 2000 – 2018



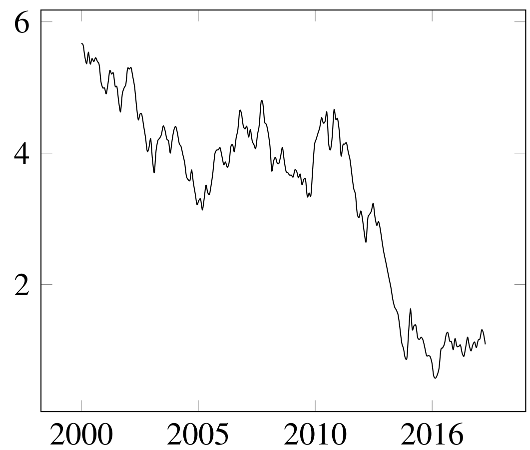
(a) Core vs Periphery (b) US vs Euro Area

Source: OECD (2020), GDP per hour worked (indicator).

Another key feature of the monetary union should also be noted: the low interest rate environment. Long-term interest rates have been falling across the union since its formation, as exhibited in Figure 2, with an even steeper reduction after 2010. Lower interest rates, in particular long-term measures, are traditionally seen as having expansionary effects on economic growth. The reasoning behind the traditional view is that, for lower levels of the interest rate, the current value of future gains increases relatively to the costs of investing at time t, thus encouraging investment.

Nevertheless, the coexistence in the last decade of the three phenomenons mentioned raises

Figure 2: Long-term Interest Rate - Euro Area



Source: European Central Bank - Statistical Data Warehouse.

an important question: can the low interest rate environment be driving the labour productivity divergence in the Eurozone?

In this regard, a mechanism advanced by Liu et al. (2019) stands out. The authors propose a model based on dynamic competition between duopolist firms, where extremely low interest rates can cause a widening of the productivity gap between leaders and followers, while giving rise to a decrease in aggregate growth. Since the model is only empirically applied to the US, it becomes of interest to evaluate to which degree its conclusions match the empirical evidence of the Eurozone.

Therefore, the contribution of this study relies on empirically assessing if the mechanism in Liu et al. (2019) is present in the Eurozone, while attempting to unveil how low interest rates, productivity gaps and low aggregate growth may be intertwined in the block. What is more, taking advantage of the firm-level data provided by *Bureau van Dijk*, it sheds light on the EA divergence debate, a topic typically discussed at the sectoral or macro level, by scrutinizing the dynamics of this period at the firm stratum.

By supposing that under the European Single Market firms can trade freely with entities of any of the countries in study, while being backed by the common currency, the hypothesis is tested at the country and at the Eurozone level. The results indicate that the asymmetric effects of the interest rate might have a role in explaining the core and periphery divergence, even though not all of the additional predictions of the model are confirmed by the data.

The remaining of the paper is structured as follows. Section 2 reviews previous literature and 3 explains the details of the model, while section 4 relates it to the Euro Area. Section 5 describes the data and variables used, followed by sections 6 and 7 that explain the methodology. Sections 8 and 9 present the results for the main hypothesis and associated predictions, whereas 10 concludes.

2 Literature Review and Hypothesis

2.1 Labour productivity divergence in the Euro Area

There is a large body of literature aimed at explaining the divergence in the productivity gains between European economies associated with the worsening of the economic performance of the block. Focusing on the Eurozone, Irac and Lopez (2015) identifies two clusters among the EA-12[1] economies: the ”South Countries Group”, composed by Greece, Italy, Portugal and Spain, commonly referred to in the literature as ”Periphery countries”, and the ”Other Countries Group” - the ”Core” (Friesenbichler and Glocker, 2019). The paper finds evidence in support of between clusters' structural divergence and draws attention to the difference between core and periphery economies regarding innovation indicators, warning that the divergence in R&D investment could be particular worrisome for periphery economies.

Sondermann (2014) uses sectoral data from the EU KLEMS database to test for productivity convergence between the EA-12 countries. Regarding the drivers of the divergence, the author draws attention to the role of three areas: education of the work force, R&D investment and regulation, proxied by the indicator provided by the Fraser Institute. As in Friesenbichler and Glocker (2019), several other studies have pointed out the role of institutional factors, assessing the role of corruption, regulation, rule of law or policy effectiveness, with measures sourced, for instance, from the World Bank's World Governance Indicators database (Sondermann, 2014; Andrews et al., 2016; Irac and Lopez, 2015). Furthermore, Irac and Lopez (2015) provides evidence in favour of a divergence in terms of the quality of institutions, which reinforces the role that these factors might

[1] BE, DE, IE, ES, FR, IT, LU, NL, AT, PT, FI.

be playing.

Another stream in the literature focuses on models of structural transformation and sectoral heterogeneity between eurozone economies (Mongelli et al., 2017). Friesenbichler and Glocker (2019) contributes to the debate with a tradable-non-tradable approach. The authors demonstrate that, between 1999 and 2015, core countries maintained their share of tradable and non-tradable goods production fairly constant, while periphery countries saw the share of non-tradable goods increase significantly until 2008. Given the unsustainable sectoral composition of these economies before the crisis, these were the ones which suffered the most serious recessions and the ones where the replacement of the production of non-tradables took place. The authors argue that the tradable sector is of higher importance for aggregate productivity and, for that reason, the way production is divided in tradable and non-tradable goods is crucial for economic catch-up. According to this reasoning, structural change towards the tradable-sector fosters convergence, and periphery economies would benefit from reallocating their production away from the non-tradable sector.

Nonetheless, the main culprits identified in the literature when it comes to common currency associated factors can be divided into three categories: capital misallocation, labour misallocation and the scale effect (Bagnai and Ospina, 2018). Bagnai and Ospina (2018) study the importance of the three effects for the productivity dynamics of 27 sectors in France, Germany, Italy and Spain from 1986 until 2014. Using the real interest rate as a proxy for capital misallocation, the real effective exchange rate to measure the scale effect and the ”strictness of employment protection” as an indicator of the role of labour market reforms, the authors estimate an Autoregressive distributed lag model with a pooled mean group estimator (ARDL-PMG) and show that the three effects have had a significant role on reinforcing divergence dynamics among the four economies.

Within the capital misallocation view, Gopinath et al. (2017) focuses on firm-level data (ORBIS) for European manufacturing firms between 1999 and 2012 to examine the capital allocation effect. With a model with heterogeneous firms, financial frictions that depend on firm size and capital adjustment costs, the authors demonstrate that the decline in the real interest rate has led Southern countries to experience larger increases in dispersion of the marginal rate of return to capital and to lower total factor productivity. Since core firms tend to have access to more developed financial markets, the TFP losses due to misallocation are not observed in northern countries, reinforcing the idea that the capital misallocation effect is particularly relevant in southern countries, where the large capital inflows following the adoption of the euro seem to have been directed at less efficient, but with higher net worth, firms.

2.2 Interest rate and the single market hypothesis

The productivity slowdown is not a unique feature of Euro Area economies and, as Liu et al. (2019) argue, its persistence suggests that a common factor with long-term effects at the global scale should be driving it. Liu et al. (2019) model the consequences of low interest rates for market competition, thus presenting a different mechanism through which the decrease in interest rates can induce lower productivity growth: a strategic behaviour. The paper studies how investment incentives are shaped by interest rate developments and how leaders and followers are differently affected according to the level of the interest rate. Therefore, the presence of the traditional expansionary effect of monetary policy ease is combined with a contractionary impact, culminating in an inverted-U relationship between interest rates and productivity growth.

Besides the productivity slowdown associated with ultra low interest rates, the model yields a series of predictions regarding the increase in the productivity gap between leaders and followers, also foreseeing a rise in market concentration and markups, along with a decline in business dynamism. The plausibility of the model is backed by findings in the literature that indicate a widen productivity gap to the global frontier and a reduction of market competition in OECD economies (Andrews et al., 2016). Moreover, Liu et al. (2019) apply the model to high-frequency US data and demonstrate that a decline in the long-term rate from an already low level of this variable is more beneficial to leaders than followers, thus validating the main conclusion of the model. The next section presents the main points of the model.

3 Model

3.1 Setup

The model nests within a two players dynamic game with *à la* Bertrand competition. To introduce the productivity gap component in the framework, profits are assumed to depend not on the productivity level of a firm, but on the productivity gap between the two players. As a consequence, the productivity gap becomes a state variable s whose path shapes the degree of market dynamism. As long as this gap s is above 0, the market will feature a leader, with profits equal to π_s, and a follower, whose profits are denoted by π_{-s}. In addition, although a greater s results in superior profits at the aggregate level, it will also mean a more unequal distribution between the participants, which will evidently benefit the leader.

3.2 Investment Decisions

To improve its productivity, a firm can invest up to η in each state s. Furthermore, investment is associated with a marginal cost of c. Thus, in each state, a firm will decide its level of investment, η_s, which will be between $[0, \eta]$, and will spend a total of $c \times \eta_s$. In turn, the productivity gap $s(t+\Delta)$, where Δ denotes time after moment t, will evolve in the following way:

- s will increase by one step with a probability of $\Delta \cdot \eta_s$;
- s will decrease by one step with a probability of $\Delta \cdot (\kappa + \eta_{-s})$;
- s will remain unchanged otherwise.

The parameter κ models exogenous technology diffusion and might be interpreted as the rate of patent expiration. Thus, introducing κ adds to the model an exogenous Poisson rate at which the laggard converges with the frontier.

The determinants of s clearly show how investment decisions become strategic. By increasing investment, a firm can expand or shorter the productivity gap of the next state. If s increases, the follower will need additional steps to reach the leader, perpetuating the leading position of the latter. A decrease in s enables the follower to get closer and eventually catch up with the frontier. Thus, players invest not only to increase productivity and obtain higher profits at a later stage, but more importantly to consolidate or improve their position in the market. The latter motive, labelled *strategic incentive*, will allow for even greater profits in subsequent states.

The long-term interest rate r becomes relevant in the model since forward looking firms will take decisions by maximising the present discounted value of future payoffs, net of investment costs. The value of each firm in state s at time t, denoted by $\upsilon_s(t)$, becomes:

$$\upsilon_s(t) = \mathbb{E}\left[\int_0^{\infty} e^{-r\tau}\left\{\pi(t+\tau) - c(t+\tau)\right\} | s\right] \tag{1}$$

For a given interest rate r, the set of value functions and investment decisions $\{\eta_s, \eta_{-s}, \upsilon_s \upsilon_{-s},\}_{s=0}^{\infty}$ that satisfy 7 and 8 constitute the symmetric Markov-perfect equilibrium of the game. The Hamilton–Jacobi–Bellman equations for each firm are presented in Appendix A.

Regarding the impact of the interest rate in the model, as the traditional view in the literature implies, a decrease in the long-term interest rate level has expansionary consequences for investment. When future profits are discounted at lower rates, the present value of future returns become relatively higher when compared to the costs of investing. According to this line of reasoning, investment and, as a consequence, growth should increase after a decrease in r.

Nonetheless, Liu et al. (2019) shed light on a contractionary effect brought by the interest rate decline from an already low level: a strategic effect caused by forward-looking firms who decide investment taking into consideration the impact their actions will have on future competition and market shares.

For sufficient low levels of the interest rate, and as the leader becomes infinitely patient, the strategic and anti-competitive effect of the decrease of interest rate will dominate the expansionary one. This happens because the leader will get stronger incentives to invest. As r decreases, the leaders has not only a lot to win by gaining more market share, but above all, it has a lot to lose with a reduction in s. A market leader that falls from the monopolistic to the competitive region would experience a drop in firm value, that would be higher the lower the interest rate gets. Therefore, to protect the proximity it has to high profit states, a leader will engage in an aggressive investment behaviour, with the aim of ruling out the chance of the follower ever closing the gap and overcoming it. It is important to note that the assumptions of the model imply that followers will only invest while reaching high-states and receiving the associated high profits is possible. If investing does not bring the possibility of a reduction in s because of the aggressive behaviour of the leader, laggards will settle and stop investing, since they have no chance of improving their profits.

The negative consequences for aggregate investment and growth are not reduced to the fact that followers cease to invest. As the leader reaches a sufficiently secure position, it will also stop investing, since the investment cost is higher than the marginal benefit brought by being one step ahead of a very lagged competitor. Whether or not the contractionary effect dominates the traditional one, is determined by the level of the interest rate. Thus, the model predicts an inverted-U relationship between economic growth and the interest rate.

The next section presents the predictions of Liu et al. (2019) regarding the environment where the long-term interest rate is low enough to allow for the contractionary effect to become dominant.

3.3 Model Predictions

Proposition 1: As the interest rate converges to zero:

1. All markets move from the competitive to the monopoly region;
2. The productivity gap between frontier and laggard firms increases;
3. The ratio of aggregate investment to GDP reduces;
4. The growth rate of aggregate productivity decreases;
5. Industry leaders become the only players in the market, obtaining large profits and mark-ups;
6. Market dynamism reduces and leader's status become permanent;

7. The market valuation of leaders increases relatively to the value of follower firms.

Proposition 1 implies that, as the interest rate decreases and becomes closer to zero, followers cease investment and leaders only invest to offset the exogenous technology diffusion, causing a decline in aggregate investment and productivity growth.

Proposition 2: As the interest rate converges to 0, the relative valuation response between leaders and followers increases and diverges to infinity.

4 The Euro Area through the Lens of This Model

The model by Liu et al. (2019) introduces a novel mechanism that establishes a long-run relationship between low levels of the interest rate, low productivity growth and increasing productivity gaps, which is precisely what has been happening in the Euro Area. The explanation for the interaction between the three does not rely on zero lower bound or price stickiness as in other branches of the literature (Moran and Queralto, 2018), but on a dynamic game between forward-looking duopolists.

With the euro as a common currency and under the European Single market, the Euro Area emerges as a candidate to test the plausibility of this model since firms can freely compete across countries while benefiting from a fixed exchange rate. What is more, applying this mechanism to the common market makes one wonder if an unequal distribution of frontier and laggard firms across countries might explain why the periphery is still lagging behind. This is the hypothesis that will be addressed in the remaining sections.

5 Data and Variables of Interest

This study will follow a firm-level approach to study not only whether the divergence between EA countries could be connected with the low interest rate environment, but also if the lack of macro convergence also reflects on significant differences at the company stratum. The firm-level databases compiled by *Bureau van Dijk*, a Moody's Analytics company focused on private enterprise data, provide a tool to bring the debate around the productivity divergence in the Euro Area, which has traditionally focused on country and sectoral data, to a more disaggregated view.

The analysis will cover the period from 2009 until 2018 and the following countries: Austria, Belgium, France, Germany, Italy, Netherlands, Portugal and Spain. Firm-level data for Portugal is sourced from the *Financials* dataset of *Sabi*, a database from *Bureau van Dijk*. The information for the other countries is obtained in the *Financials* dataset of *Amadeus*, also from *Bureau van Dijk*, via the Wharton Research Data Services (WRDS). In terms of industries, the firms kept belong to the sectors with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the European Classification of Economic Activities system NACE Rev. 2. Thus, the analysis excludes primary sector activities, financial services and public services. Since the financial databases only provide annual data, this analysis will focus on the predictions that have implications on an annual basis. This will restrict the study to the implications of Proposition 1.

Variable transformations, computations, data filtering and cleaning will follow mostly Gal (2013), and a detailed description of the variables used can be found in Appendix C. Nominal variables are deflated at the 2 digit industry level using OECD detailed National Accounts data and expressed in 2015 euros.

Due to missing data, the sample becomes less representative in terms of firms and countries after data treatment. To correct for that, all the averages in the empirical results sections are weighted by the share of the countries in the initial sample available in the Financials database of Amadeus. Also due to the low representativeness of small firms in the dataset, only firms with at least 20 employees will be part of the final sample.

5.1 Productivity

First and foremost, productivity will be measured primarily by Multi-factor productivity (MFP) and expressed in log terms. In additional tests, Value Added per worker will also be used as a measure of labour productivity. Multi-factor productivity will be estimated using a Cobb-Douglas production function based on value added and with the number of employees and real capital stock as inputs, having as reference the work by Petrin and Levinsohn (2012). As proposed by Wooldridge (2009), the *Wooldridge-Levinsohn-Petrin* approach estimates the production function by using intermediate inputs, in this case materials, as a proxy for unobserved productivity. Furthermore, twice lagged values of labour act as instruments for the variable, addressing the identification issues regarding β_l raised by Ackerberg et al. (2015). Production functions will be estimated at the eurozone level but separately for each two digit NACE industry, controlling for country and year fixed effects. Not estimating production functions separately for each EA member allows for the comparison of MFP measures across the Eurozone.

5.2 Productivity Frontier

The frontier at time t includes the top 5% of the estimated multi-factor productivity distribution for each two digit sector. Since the total number of firms available varies from year to year, using a measure that depends solely on the absolute number of firms per period could potentially underestimate the value of the frontier when the amount of firms available is much larger than the median. To circumvent this issue and prevent laggards from ascending to the top in these times, we compute the median total number of companies across the period and use this measure to find a fixed size for the frontier set. Therefore, the 5% of this median will the proxy for 5% top of the productivity distribution. It is important to note that, although the number of firms is fixed overtime, the composition of the frontier is allowed to change. ”Laggard firms” is composed by all the other companies.

Having identified the group of leaders, the productivity frontier value at time t in industry s will be the unweighted average of the Multi-factor productivity of the companies that belong to the set of leaders. As Griffith et al. (2004) highlight, using this measure instead of the value of the firm with the highest productivity at time t enables one to circumvent possible measurement errors in the productivity variables.

5.3 Productivity Gap

The main outcome of interest will be the Multi-factor Productivity Gap between frontier and laggard firms, which will measure the distance of a firm to the market leaders. Since MFP is expressed in log terms, the same will apply to the gap variable, computed in the following way:

$$Gap_{isct} = MFP_{Fst} - MFP_{isct} \tag{2}$$

In equation 2, MFP_{Fst} denotes the technology frontier of sector s at time t, and is unique at the country or at the single market level.

5.4 Real Interest Rate

The main independent variable, the long-term real interest rate, will be proxied by the difference between the annual frequency transformation of 10-year government bonds and the annual inflation rate for each country. All nominal long-term interest rates, including the nominal index for the Eurozone, are sourced from the Statistical Data Warehouse of the European Central Bank.

6 Empirical Framework

This section presents the methodology used to test the main hypothesis: the low interest rate environment might have a contractionary effect by discouraging competition, which could explain not only part of the productivity slowdown of the Eurozone, but also the increasing divergence between the core and the periphery of the union. The mechanism can operate in the context of the Euro Area in two ways: at the country or at the single market level. Nonetheless, the predictions of Liu et al. (2019) imply that the negative effect of the interest rate is only present for sufficiently low levels of the variable. Thus, finding the mechanism at the country level does not imply nor rule out the presence of the contractionary effect of the interest rate at the Eurozone level, or vice-versa. The interest rate might already have crossed the threshold in one, in both or in none of the cases.

6.1 Country Level

For country level tests, contrasting the effect in Italy and Germany becomes of interest not only due to the different paths of the long term government yields of the two countries[2], but also because they might as well be the two most common choices to represent each of the opposite sides in the literature, with Italy on the periphery and Germany on the core side. Individual tests will also be extended to Portugal, whose poor growth performance after joining the Monetary Union clashes with the convergence expectations that many had before the turning of the century (Lains, 2019).

Considering the high level of disaggregation of the panel, the baseline model will include firm-specific effects to control for unobserved heterogeneity across firms that could potentially bias the results (Cameron and Trivedi, 2005). The resulting fixed effects model is:

$$Gap_{ist} = \alpha_i + \beta_1 X_{ist} + \beta_2 CountryR_t + \beta_3 EuroAreaR_t + D_t + \varepsilon_{ist} \tag{3}$$

In equation 3, α_i are firm fixed effects and X_{ist} denote the firm-level controls, namely firm age and its squared term, number of employees and turnover. The last two covariates are taken in logs. $CountryR_t$ is the real long-term interest rate of the country in question, while $EuroAreaR_t$ is the indicator for the real long-term interest rate in the Eurozone. Lastly, D_t are year dummies and ε_{ist} is the idiosyncratic error. Errors are clustered at the industry level to allow for correlation between firms in the same sector. Clustering only at the firm level would assume all firms are independent, which could lead to erroneous inference.

When dealing with annual data, it is very likely that firms have time to make decisions, invest and see the consequences of their investment reflected in the market within the same period in which monetary policy changes take place. Nonetheless, the model assumes that even though firms make investment decisions at state s based on the information available at that time, market changes will only be felt in the next state, when the new productivity gap of $s+1$ is known. Therefore, to control for potential endogeneity, all explanatory variables are lagged by one year.

[2] Annual 10-year real interest rates in Germany ranged from -1.5 to 3.02 in the period, whereas the Italian ranged between 0.81 and 3.51.

Regarding robustness, the Hausman test is performed in each case to assess whether the random effects is the efficient estimator or if, on the contrary, it would be inappropriate to use it due to the existence of non-random and unobserved firm-specific effects. Finally, since the decisions of firms may depend on unobserved factors that are correlated across time, the Arellano-Bond estimator will address potential issues of serial correlation in the error term (Arellano and Bond, 1991; Roodman, 2009).

6.2 Single Market Context

As in the baseline model for country level tests, the preferred specification for the Eurozone will also include firm fixed effects. Nonetheless, another key issue ought to be accounted for when working with the full dataset. Due to missing data, the sample becomes less representative in terms of firms across countries after treatment and filtering. For that reason, the regression will account for the weights of each country in the initial sample, ensuring that the estimates are not driven by the over or under representativeness of a certain nationality.

The goal in this new context is to first see if the effect is acting in the Euro Area as a common market, without accounting for country level factors. Thus, the baseline model becomes:

$$Gap_{isct} = \alpha_i + \beta_1 X_{isct} + \beta_3 EuroAreaR_t + D_t + \varepsilon_{isct} \tag{4}$$

As a starting point to see if differences in productivity exist across countries, figure 3 compares the share of firms that belong to the European frontier in each country in selected years. As a second step, we attempt to disentangle the common market effects from the country ones, by adding country factors:

$$Gap_{isct} = \alpha_i + \beta_1 X_{isct} + \beta_2 X_{sct} + \beta_3 X_{ct} + \beta_4 EuroAreaR_t + \beta_5 P_c + D_t + \varepsilon_{isct} \tag{5}$$

Comparing to equation 4, country level covariates X_{ct} are introduced to account for the different characteristics of the countries. The variables chosen to control for institutional and regulatory differences are the ”Legal system and property rights” and ”Regulation” indicators of the Fraser Institute. Given the multilevel structure of the data, sectoral concentration measures for each country are included in X_{sct} as sector level covariates for a specific country. To assess whether belonging to a periphery or a core country have different effects on the distance of a firm to the euro frontier, one can introduce a dummy variable P_c that equals 1 if the country is classified as a periphery EA member in the literature. Even though the coefficient of this variable cannot be computed with the within estimator, the System Arellano-Bond estimator is capable of doing it, by only including this variable in the level equation and not in the differenced one. Thus, with this method, one is still able to study the impact of time-invariant variables while still controlling for firm fixed effects and serial correlation in the residuals.

For robustness, both models will be estimated with the within estimator to control for firm-specific heterogeneity unless the Hausman test proves otherwise. Furthermore, as discussed in section 6.1, all variables will be instrumented for with its own lagged values and, if needed, serial correlation in all specifications will be corrected with the System GMM.

7 Methodology for Additional Predictions

Besides the impact of a decrease of the interest rate on the MFP gap, section 3.3 presents a set of additional predictions that would help validate the model. Taking advantage of the firm level data, this analysis begins by comparing productivity growth rates of frontier and laggard firms. Next, the evolution of capital stock and MFP will also be compared, to assess whether one of them has a bigger importance as a driver of the productivity gap. The bulk of this section explains the more elaborate steps taken to study the possible additional consequences for the economy.

7.1 Consequences for sectoral productivity

Point 4. of Prediction 1 entails that industries where the aggregate productivity is falling the most are the industries where the productivity gap between leaders and followers is rising the most. To evaluate if MFP divergence within a sector affects productivity growth in that sector as a whole, the industry MFP growth is regressed on the lagged value of the average productivity gap of laggard firms. As robustness check, the Arellano–Bond estimator is also computed.

7.2 Follower catch-up

The increase in leadership persistence foreseen by point 6. would imply that, as the productivity gap increases, it gets harder and harder for the follower to converge. However, the literature of neo-Schumpeterian growth theory argues the opposite. Due to knowledge diffusion and technology spillovers, the more a firm is behind the frontier, the more it should grow when compared to the average growth rate of the sector (Aghion et al., 2013). In line with this literature, Griffith et al. (2004) study the latter hypothesis and present evidence in favour of productivity catch-up with the frontier. Following this literature, an Error Correction Model, where productivity growth of non-frontier firms depends mainly on the distance to the frontier, will be estimated. As in Andrews et al. (2016), an interaction term between the gap and a time period will be added to the baseline specification so as to evaluate whether the pace of convergence has increased or decreased over time. The baseline model to be tested empirically will account for firm level fixed effects and will be the following:

$$\Delta MFP_{isct} = \delta_1 \Delta MFP_{Fst} + \delta_2 gap_{isct-1} + \sum_j \delta_3^j gap_{isct-1} \times D_t^j + \delta_4 X_{isct} + \gamma_i + \delta_{ct} + \varepsilon_{isct} \quad (6)$$

As in previous models, X_{isct} is the set of firm level covariates and lagged values of all variables control for potential endogeneity. D_t^j is a dummy variable that equals 1 if the year belong to the j period. In this case, three periods will be considered: 2009-2012, 2013-2015 and 2016-2018. γ_i are firm fixed effects and δ_{ct} includes country*time dummies to control for technology and macroeconomic innovations that may impact all firms within the same country and year. Lastly, errors are clustered at the industry and country level. This way, it is assumed that the errors are independent across industries and countries, which allows the error term to be correlated across firms within the same sector and country.

Without further controls, the coefficient on gap_{isct-1} is expected to be positive as in the literature. Nonetheless, if decreasing the long-term interest rate has a negative impact on the growth of a non-frontier, then the coefficient on gap_{isct-1} should increase after controlling for it.

7.3 Market dynamism and concentration

Points 1., 5. and 6. of Proposition 1 focus on the degree of concentration and dynamism of the market. Firstly, leadership persistence is studied by computing the share of frontier firms at time t that were at the top of the MFP distribution two years earlier.

Secondly, an idea of entry and exit dynamics can be obtained by plotting the share of firms by age across the sample. Firms will be allocated into age categories in accordance with Andrews et al. (2016). The groups are the following: young firms, mature firms, non-viable old firms (with at least two consecutive years of negative profits) and viable old firms. Since the model predicts a reduction on the degree of business dynamism, one should expect to see a decrease in the share of young firms. Regarding non-viable old firms, or *zombie firms* as referred in the literature (Banerjee and Hofmann, 2018), two hypothesis can be advanced. The share of non-profitable old firms can increase as these companies reduce investment, productivity and, as a consequence, experience profit losses. Some studies have argued that low interest rates have lead to the increasing prevalence of mature firms with negative profits over consecutive periods (Banerjee and Hofmann, 2018). However, these firms will only persist in the market if the banking sector provides the necessary credit support (Acharya et al., 2019). If non-profitable and highly indebted companies saw their access to credit halted in the period and had to declare bankruptcy, the data might show a reduction of the share of zombie firms.

Lastly, concentration measures will follow Bruno et al. (2019) and Kalemli-Ozcan et al. (2015) and equal the market share in terms of operating revenue (or turnover) of the top 4 (*MS4*) or 8 (*MS8*) firms in the industry. To study how the indicators evolve over time, the separate averages for the manufacturing and services sectors are presented.

7.4 Investment

Prediction of point 3. foresees a decrease in sectoral investment to GDP ratio as low interest rates reach values close to zero. In the model, this stems from the growing difference between the incentives of leaders and followers to invest. As the productivity gap between leaders and followers increases, the likelihood that followers are able to reach a leadership position decreases, which decreases their incentives to invest in order to surpass the frontier firm. This reasoning originates three conclusions that should be present in the data for the model to hold.

First, investment by leaders should be rising faster than the one by laggards, which can be assessed by comparing growth rates of the investment to value added ratio in the two cases. Second, an increase in the gap between leaders and followers should also lead to an increase in the investment gap between them. Lastly, as the investment gap widens, investment to GDP ratio should decrease at the sectoral level. The last two statements will be tested by first correlating the two gaps, and then regressing the Sectoral Investment to Value Added Ratio on the lagged value of the investment to value added ratio gap variable and on the lagged MFP gap.

8 Empirical Results

8.1 Country Level

Tables 1, 2 and 3 present the empirical results for the main hypothesis at the country level. Specification tests and robustness details are explained in Appendix D.1. When comparing the coefficients on the country-specific real Interest Rate obtained with the fixed and System GMM estimators in the three tables, one concludes that the sign of the coefficients of the two Southern countries are the symmetric of the German one. While a decrease in the interest rate for the periphery countries could reduce the MFP gap within the country, the same drop in the long term government bonds would mean an increase in the distance to the frontier of German followers within national borders.

Nonetheless, the fact that the coefficients regarding their own government yields are positive for Italy and Portugal could mean, according to the reasoning of the model, that these variables have

Table 1: Interest Rate Effect at the Country Level - Portugal

	(1) Gap_{ist}	(2) Gap_{ist}	(3) Gap_{ist}	(4) Gap_{ist}
$PortugalR_{t-1}$	0.00248	-0.00104	0.00349	0.00703
	(0.59)	(-0.23)	(1.00)	(1.50)
$EuroAreaR_{t-1}$	-0.0327^{+}	-0.00504	-0.0456*	0.00179
	(-1.84)	(-0.50)	(-2.37)	(0.18)
Gap_{ist-1}			0.186***	0.308***
			(3.85)	(3.99)
Estimator	Within	Multilevel RE	Within	System GMM
Year Dummies	Yes	Yes	Yes	Yes
Industry Fixed Effects	-	No	-	-
N	78759	78759	78759	78759
R^2	0.045		0.074	

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Clustered Standard Errors at the 2 digit industry level. All regressions include firm age and size (turnover and employment) controls.

not reached a sufficiently low level for the contractionary effect to dominate the expansionary one. Long-term interest rates in Germany are indeed much lower than the ones experienced in the other two countries[3], which helps to support the conclusion of the model: the mechanism only operates for sufficiently low levels of the monetary variable.

Table 2: Interest Rate Effect at the Country Level - Germany

	(1) Gap_{ist}	(2) Gap_{ist}	(3) Gap_{ist}	(4) Gap_{ist}
$GermanyR_{t-1}$	-0.0409***	-0.0504***	-0.0572***	-0.294***
	(-3.70)	(-3.48)	(-7.85)	(-8.88)
$EuroAreaR_{t-1}$	0	0.101***	0	0.474***
	(.)	(5.89)	(.)	(8.10)
Gap_{ist-1}			0.273***	0.329***
			(5.41)	(6.49)
Estimator	Within	Multilevel RE	Within	System GMM
Year Dummies	Yes	Yes	Yes	Yes
Industry Fixed Effects	-	No	-	-
N	64712	64712	64712	64712
R^2	0.113		0.186	

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Clustered Standard Errors at the 2 digit industry level. All regressions include firm age and size (turnover and employment) controls.

Including the $EuroAreaR_{t-1}$ variable in the regressions also allows to control for possible non-linear effects of the long-term interest rate, since the values for this indicator are higher than the

[3] Annual 10-year real interest rates in Germany ranged between -1.5 and 3.02 in the period, while the Portuguese and the Italian from 0.64 to 7.75 and 0.81 to 3.51, respectively.

German real interest rate, but lower than the other two economies. For instance, the positive coefficient on $EuroAreaR_{t-1}$ in specification (3) of table 2 might indicate that, for higher values of the long-term interest rate, the expansionary effect could again become dominant in Germany. Since, in general, the sign of the same coefficient is negative for periphery countries, the opposite reasoning applies: lower base values of the interest rate could in turn imply within country divergence.

Table 3: Interest Rate Effect at the Country Level - Italy

	(1)	(2)	(3)	(4)
	Gap_{ist}	Gap_{ist}	Gap_{ist}	Gap_{ist}
$ItalyR_{t-1}$	0.00468	0.00598	0.0194*	0.187***
	(0.47)	(0.71)	(2.34)	(4.56)
$EuroAreaR_{t-1}$	0	-0.0252**	0	-0.0538***
	(.)	(-2.89)	(.)	(-3.56)
Gap_{ist-1}			0.289***	0.394***
			(23.67)	(12.76)
Estimator	Within	Multilevel RE	Within	System GMM
Year Dummies	Yes	Yes	Yes	Yes
Industry Fixed Effects	-	No	-	-
N	321697	321697	321697	321697
R^2	0.073		0.134	

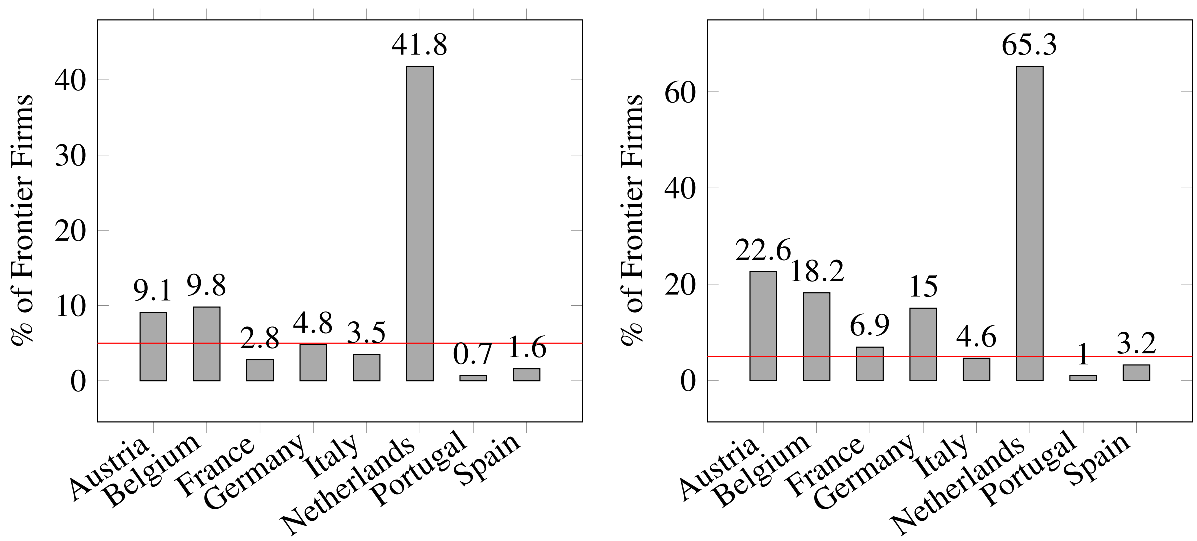
Notes: t statistics in parentheses. $^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Clustered Standard Errors at the 2 digit industry level. All regressions include firm age and size (turnover and employment) controls.

8.2 At the Euro Area Level

Before studying the effect of the interest rate on the MFP gap at the common level, this segment starts by seeing if there is enough evidence in the sample to distinguish between core and periphery countries. If frontier firms were evenly distributed across countries, 5% of the firms in each country would belong to the European frontier while the other 95% would be market followers. Figure 3 plots the share of firms in each country that belong to the European frontier in 2009 and 2018. In both years, the shares of frontier firms in periphery countries are all below the 5% threshold. The fact that this does not happen in the countries usually classified as core, might be indicative of MFP differences at the firm level that have implications at the aggregate level. Thus, it is an indication of how relevant studying the determinants of the productivity gap at the firm level could be.

Regarding the study of the signal of the interest rate effect, the results of the models described

Figure 3: % of firms of each country that belong to the Single Market Frontier



(a) Year of 2009 (b) Year of 2018

Notes: Frontier firms are defined as the top 5% of the Multi-factor productivity distribution. The industries included are the ones with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the NACE Rev. 2 system. The figure compares the share of leaders as a percentage of the total number of companies in each country instead of looking at the share of each nationality in the group of frontier firms because, due to missing data, some countries are less well represented in the treated sample. The high percentage of frontier Dutch firms can also be biased by the type of firms that are retained in the sample.

Source: Author's calculations based on the Amadeus and Sabi databases.

Table 4: Interest Rate Effect at the Eurozone Level

	(1)	(2)	(3)	(4)	(5)	(6)
	Gap_{isct}	Gap_{isct}	Gap_{isct}	Gap_{isct}	Gap_{isct}	Gap_{isct}
$EuroAreaR_{t-1}$	-0.0129*	-0.0163**	-0.0725***	-0.00556^{+}	-0.0513***	-0.0367***
	(-2.42)	(-3.00)	(-11.49)	(-1.90)	(-9.00)	(-6.84)
$Regulation_{ct-1}$		-0.0105	-0.0140^{+}		-0.186***	-0.124***
		(-1.04)	(-1.96)		(-7.50)	(-5.15)
$LegalSystem_{ct-1}$		-0.0112	-0.0158		0.00422	0.0760*
		(-0.73)	(-1.46)		(0.20)	(2.12)
Gap_{isct-1}			0.301***	0.449***	0.494***	0.474***
			(43.05)	(20.03)	(23.57)	(23.74)
$Periphery_c$						0.163**
						(2.77)
Estimator	Within	Within	Within	System GMM	System GMM	System GMM
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	797109	797109	797109	797109	797109	797109
R^2	0.089	0.089	0.159			

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Clustered Standard Errors at the country and 2 digit industry level. All regressions are weighted by the initial sample share and include firm age and size (turnover and employment) controls.

in section 6.2 are presented in table 4. The results are robust across specifications and indicate that a decrease in the interest rate contributes to an increase in the productivity gap. Furthermore, as additional variables are added to control for country institutional differences, the coefficient on $EuroAreaR_{t-1}$ increases in absolute value and gains significance. Therefore, the results of table 4 seem to be in accordance with the main hypothesis presented: a decrease is the interest rate could widen the gap between market leaders and followers. Thus, the low interest rate environment could be having negative consequences at the firm level, particularly for productivity dynamics of market followers. Given the unequal distribution of frontier firms across the common market found in Figure 3, this negative effect at the firm level could exacerbate country level divergence and help explaining, at least in part, why the periphery struggles to converge since it joined the euro.

Regression (5) reinforces the conclusions drawn in favour of the main hypothesis. The positive sign of the coefficient on the *Periphery* dummy indicates that being in a periphery country might in fact increase the gap of a firm to the European frontier. This provides additional evidence for the hypothesis that the aggregate divergence of periphery countries could be related to a significant divergence of productivity at the firm level.

Concerning other factors that could be relevant in explaining differences across the EA, the Regulation[4] coefficient presents a negative sign: a higher score in the index should reduce the gap between frontier and laggards. Since an increase in the coefficient means that a country has reduced market regulation, the results indicate that adopting pro-market reforms could reduce the MFP gap. On the other hand, the Legal System index is not robust across specifications.

9 Mechanism Validation

Table 10 contrasts the mean characteristics for frontier and laggard firms based on the MFP distribution for the year of 2018. In both sectors, frontier firms have more employees, higher capital-to-labour ratios, investment values and turnover. Moreover, they pay higher wages than other firms.

[4] A higher score in the Regulation Index means a less rigid credit, labour and business market with less restraints imposed by the government. Countries with anti-competitive policies in place have lower scores in *Regulation*.

Figure 4 compares the growth rates of the average value added per worker of frontier and laggard firms in the total sample, separately for the manufacturing and services sector. In the manufacturing industry, while labour productivity of laggards firms increased from 2009 to 2018, the one of frontier firms actually decreased, on average. Regarding services, even though the growth rates are negative for both types of players, the decrease in productivity was stronger for frontier than for non-frontier. This seems to indicate that, on average, firms within the eurozone are not necessarily diverging, at least when cross-country differences are not controlled for. The same pattern of growth emerges for Multi-factor productivity. When it comes to capital deepening (Figure 6), while a divergence in the manufacturing sector is still not visible, the same cannot be said about the services sector. Here, capital deepening is stronger for frontier firms. Thus, between this variable and MFP, the latter seems to be the one driving the differences in value added per worker. If it was not, then the fall in labour productivity would not have been so strong in the Services sector.

9.1 Aggregate Productivity and MFP Gap

Table 12 displays the results of the regression of Multi-factor productivity growth at the sectoral level on the average gap between frontier and laggard firms in the same sector. Even though the coefficient on the lagged value of the gap is not significant in all specifications, the negative coefficient in the three columns provides evidence in support of the hypothesis of the model: a higher average gap between followers and leaders can be associated with a lower MFP growth rate for the sector. Thus, increasing distances to the frontier might bring lower aggregate growth.

9.2 Catch-up with the frontier

The results for equation 6 are shown in table 13. As expected, the coefficient on the distance to the leader is positive across all specifications. Moreover, adding the interest rate in regression (2) does not affect the coefficient on the gap. With the system GMM estimated in column (4), the effect on the gap seems to reduce after including the interest rate, but the coefficient on the latter is positive and significant. Thus, the results do not seem to support the hypothesis that the low interest rate mechanism has affected the importance that technology spillovers have on MFP growth. Firms further behind the frontier of this eurozone sample still seem to grow faster, at least without controlling for country factors. Lastly, unlike what Andrews et al. (2016) conclude, the pace of convergence does not seem do have reduced over the period. The coefficients on the interaction terms with the time dummies are positive across three of the four columns, which indicates that the effect might be stronger in the last two periods when compared to the base effect of 2009-2011.

9.3 Market Dynamism

Figure 7 confirms the leadership persistence predicted by the model. From 2011 to 2018, the percentage of frontier firms that had been leaders two periods before increased from around 30% to 50%. In 2018, around 70% of the frontier firms were in the top 20% of the MFP distribution at time $t-2$. Concerning market dynamism, core and periphery countries experienced an increase in the share of young firms, which goes against the reasoning of the model (Figure 8). Nonetheless, the path of non-viable old firms is different for the two groups. The share of these companies seems to have dropped in the periphery, while increasing in the core. As mentioned, without further analysis, it is hard to say if a lower share of these companies signals a decrease of zombie firms, or higher bankruptcy rates. Moreover, concentration measures in Figure 9 suggest a decrease in concentration after 2009 (perhaps driven by the sovereign debt crisis), especially for the manufacturing sector, followed by a slight increase in recent years. Finally, Figure 10 reveals that the increase in markups for frontier firms was particularly important in the manufacturing sector, but was not featured in services. In sum, the leadership persistence hypothesis is backed by the data, while concentration and market dynamism measures do not show the adverse scenario implied by the model.

9.4 Investment

Figure 11 compares the growth rates of the investment to value added ratio between frontier and non-frontier firms, separately for manufacturing and services sectors. From 2009 to 2018, investment rates are similar for the two types of companies in the manufacturing sector. Nonetheless, panel (b) appears to indicate that investment rates were higher for market leaders in the services sector. When it comes to other indicators, the investment ratio gap and the multi-factor divergence measure display a positive correlation. Nonetheless, unlike what the model would imply, the correlation coefficient is small (0.111). Table 14 displays the results regarding the implications for sectoral investment. In general, the coefficients on the Investment to Value added ratio and MFP gap are not significant. Moreover, while the former exhibits positive coefficients, the latter shows a negative effect on Sectoral investment. In sum, even though the MFP gap might have a negative impact on the Sectoral Investment ratio, the results are not significant and there is no evidence in favour of negative aggregate consequences of an increase of the investment gap. An important drawback of this analysis is that it does not account for other investment besides the one in tangible fixed assets, leaving aside expenses on intangibles and on kinds of R&D (Corrado et al., 2006).

10 Conclusion and Discussion

Throughout this study, the model of Liu et al. (2019) was applied to the Euro Area with the aim of understanding whether low interest rates could have an asymmetric impact on productivity growth at the country and the Euro level. The empirical tests conducted provided evidence in favour of a potential negative effect of low long-term interest rates for the convergence among EA countries. Even though not all additional predictions of the model seem to hold, the Multi-factor productivity gap between frontier and non-frontier firms seems to have a negative response to a decrease in the long-term interest rate when looking at the period from 2009 to 2018.

If this mechanism is truly operating in the Eurozone, it poses a question to the approach aimed at tackling the current pandemic crisis. Given the main hypothesis here proposed, unconventional monetary policy measures to bring the shadow interest rate down could exacerbate the effects of the mechanism, accentuating the differences between core and periphery countries, which are precisely the ones that are being more hurt by the pandemic. Ultimately, it could result in a sluggish economic recovery driven by increases in market concentration and lower investment.

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Appendices

A Additional Model Details

The Hamiltonian-Jacobi-Bellman equations for both firms in state $s \geq 1$ are:

$$r\upsilon_s = \pi_s + (\kappa + \eta_{-s})(\upsilon_{s-1} - \upsilon_s) + \max_{\eta_s \in [0,\eta]} \{0, \eta_s(\upsilon_{s+1} - \upsilon_s - c)\} \tag{7}$$

$$r\upsilon_{-s} = \pi_{-s} + \eta_s(\upsilon_{-(s+1)} - \upsilon_{-s}) + \kappa(\upsilon_{-(s-1)} - \upsilon_{-s}) + \max_{\eta_{-s} \in [0,\eta]} \left\{0, \eta_{-s}(\upsilon_{-(s-1)} - \upsilon_{-s} - c)\right\} \tag{8}$$

In state zero, the HJB become:

$$r\upsilon_0 = \pi_0 + \eta_0(\upsilon_{-1} - \upsilon_0) + \max_{\eta_0 \in [0,\eta]} \{0, \eta_0(\upsilon_1 - \upsilon_0 - c)\} \tag{9}$$

B Data

Firm-level data is obtained using the private company datasets compiled by *Bureau van Dijk*. Firm-level data for Portugal is sourced from the *Financials* dataset of *Sabi*. The information for Austria, Belgium, France, Germany, Italy, Netherlands and Spain is obtained in the *Financials* dataset of *Amadeus*, via the Wharton Research Data Services (WRDS). All data was retrieved in April 2020. Sabi contains information on Spanish and Portuguese companies, while Amadeus comprises all European Countries.

Regarding firm levels variables, the following were extracted individually for each country from Sabi or BvD Amadeus Financials: ID Number; Close Date; NACE REV.2, primary code; Consolidation Code; Year of Incorporation date; Tangible Fixed Assets; Number of employees; Operating revenue (Turnover); Gross profit; P/L for the period [=net income]; Taxation; Material Costs; Costs of employees; Depreciation; Interest paid.

The steps of cleaning and filtering the data for the research process were based on Gal (2013), who provides a guide on how to measure productivity at the firm level using Orbis, the international database also by *Bureau van Dijk*. The procedures adopted were the following: dropping duplicates in terms of year and id, and keeping consolidated accounts if it implies choosing between unconsolidated and consolidated financial information; dropping observations if the country code in the BvD ID does not match the country's ISO code; eliminating companies with negative values for tangible fixed assets; dropping firms with less than 20 employees or missing values for the variable; interpolating depreciation and fixed tangible assets values; dropping observations for which labour or MFP productivity, number of employees, capital, capital ratio, materials and value added are in the top or bottom 1% of the growth distribution.

Table 5: Sector and Country Level Variables

Variable name	Description	Source
Sector MFP	TFP (VA based) index, 2010=100	EU KLEMS
Sector Investment	GFCF, All assets, volume 2010 ref.prices	EU KLEMS
Sector Gross Value Added	GVA, volume 2010 ref.prices	EU KLEMS
Value Added Deflator	Gross Value Added Deflator, 2015=100	OECD detailed national Accounts
Investment Deflator	Gross Fixed Capital Formation Deflator, 2015=100	OECD detailed national Accounts
Intermediates Deflator	Intermediate Consumption Deflator, 2015=100	OECD detailed national Accounts
Long-term Nominal Interest Rate	Long-term interest rate for convergence purposes - 10 years maturity, denominated in Euro	European Central Bank - Statistical Data Warehouse
Inflation Rate	HICP Annual average rate of change	Eurostat
Regulation	Index on a scale of 0 to 10, from the most to the least regulated	Economic Freedom Rankings, Fraiser Institute
Legal System and Property Rights	Effectiveness of the protective functions of government Index, on a scale of 0 to 10	Economic Freedom Rankings, Fraiser Institute

C Variable Definitions

The use of the firm-level dataset for research purposes requires creating a set of new variables needed for the analysis, including:

- Value added = gross profits + costs of employees = profit (net income) for the period + Depreciation and amortization + taxation + interests paid + cost of employees;
- Labour Productivity = real value added divided by the number of employees.
- Starting value of real capital stock = book value of fixed assets deflated by the investment deflator;
- Gross investment = annual change in book value of fixed tangible assets + depreciation, deflated by the gross capital formation deflator.
- Capital Stock $K_{it} = K_{it-1}(1-\delta_{it}+I_t)$, using the perpetual inventory method (PIM) .
- Firm age = Current year - year of incorporation
- Concentration Index using the market share of the top 4 or 8 companies in each 2 digit sector and year;
- Multi-factor Productivity (MFP) is estimated using a Cobb-Douglas production function based on value added and with the number of employees and real capital stock as inputs, having as reference the work by Petrin and Levinsohn (2012). The production function is estimated separately for each 2-digit industry but pooled across all countries, controlling for country and year fixed effects. Errors are clustered at the 2 digit level. As proposed by Wooldridge (2009), the *Wooldridge-Levinsohn-Petrin* approach estimates the production function by using intermediate inputs, in this case materials, as a proxy for unobserved productivity. Furthermore, a 3^{rd} degree polynomial containing 2^{rd} and 3^{rd} order combinations of materials and capital lagged values, along with the twice lagged values of labour, act as

instruments in the GMM estimation. Therefore, the identification issues regarding β_l raised by Ackerberg et al. (2015) are also addressed but in a one-step GMM.

- Mark-up computations follow De Loecker and Warzynski (2012). First, the authors compute the wage share of the corrected value added. For the latter, the authors provide a Stata code that first computes all the 2^{rd} and 3^{rd} order possible combinations of materials, labour and capital values. Then, it estimates a regression of the value added on the polynomial that results from the first step, including country, industry and year fixed effects. The residuals that result from the last regression, are subtracted from the log value of the value added. This way, the unexpected component of the value added is purged from the variable. Having the corrected value added, one can finally compute the wage share first mentioned. The final step to obtain the mark-up measures is simply to divide the β_l obtained in the MFP estimation by this wage share.

Variables are deflated using the OECD deflators from the ”Detailed annual National Accounts” for Gross Value Added, Intermediate Consumption and Gross Fixed Capital Formation at the two digit industry level. When a deflator is missing for a specific year in a two digit industry, the growth rate of the subgroup above is used to compute an estimate for that year. If there are no values available for the subgroup of the industry, the deflator for the value added of the total economy is used. The same is done for intermediate consumption and investment.

D Interest Rate results - specification tests

D.1 Country level

When it comes to whether a fixed or a random effects model is the better choice for the data, the Hausman test for each of the three countries rejects the null hypothesis of no systematic differences between the random and the fixed effects coefficients. Thus, it is important to have in mind that the random effects coefficients are likely to be biased when interpreting the results.

Regarding robustness, the correlation between the dependent variable and its lag should be computed to decide whether a dynamic model should be estimated or not. In the case of Gap_{isct}, the Pearson's correlation coefficient with the lagged value is 0.8888, 0.9061 and 0.9112 for Portugal, Germany and Italy, respectively. The high correlation coefficients indicate that the dependent variable is very persistent. Thus, accounting for AR(1) dynamics with a dynamic panel data model is relevant to determine if the results are robust. First, the estimator used is a fixed effect estimator to confirm the statistical significance of the coefficient on Gap_{isct-1} that can be verified in columns (3) of tables 1, 2 and 3. Since the dataset is a small T but large N panel, the System GMM code of Roodman (2009) based on the estimator by Arellano and Bond (1991) is used to address the potential Nickell bias (Nickell, 1981).

D.2 Eurozone level

Once again, the Hausman test rejects the null hypothesis of no systematic differences between the random and the fixed effects coefficients. Thus, only the fixed effects estimator is computed.

For robustness, the correlation between the dependent variable and its lag should be computed to decide whether a dynamic model should be estimated or not. In the case of Gap_{isct}, the Pearson's correlation coefficient with the lagged value in the full sample is 0.9355. The high correlation indicates that the Gap_{isct} variable is very persistent, as one should expect since it measures the productivity distance of a market followers to the technology frontier. Given the high persistence of the dependent variable, a dynamic panel data model is estimated. First, the estimator used is a fixed effect estimator to confirm the statistical significance of the coefficient on Gap_{isct-1} that can be verified in column (3) of table 6. The estimator for the remaining steps is the System GMM as in section D.1, for the same reasons.

Table 6: Interest rate effect on MFP gap

	(1) Gap_{isct}	(2) Gap_{isct}	(3) Gap_{isct}	(4) Gap_{isct}	(5) Gap_{isct}	(6) Gap_{isct}
Age_{isct-1}	-0.0134***	-0.0140***	-0.0318***	-0.000272	-0.0000997	-0.0000442
	(-4.36)	(-4.56)	(-10.06)	(-0.97)	(-0.46)	(-0.19)
Age^2_{isct-1}	0.0000344***	0.0000334***	0.0000184**	0.000000758	0.000000255	0.000000340
	(3.72)	(3.71)	(2.72)	(0.76)	(0.31)	(0.39)
$Employees_{isct-1}$	0.196***	0.196***	0.0590***	0.0434*	0.0127	0.0103
	(26.34)	(26.23)	(8.99)	(2.58)	(0.92)	(0.71)
$Turnover_{isct-1}$	-0.292***	-0.292***	-0.113***	-0.137***	-0.0980***	-0.0959***
	(-33.01)	(-33.12)	(-16.66)	(-10.25)	(-9.28)	(-8.80)
$EuroAreaR_{t-1}$	-0.0129*	-0.0163**	-0.0725***	-0.00556+	-0.0513***	-0.0367***
	(-2.42)	(-3.00)	(-11.49)	(-1.90)	(-9.00)	(-6.84)
$Regulation_{ct-1}$		-0.0105	-0.0140+		-0.186***	-0.124***
		(-1.04)	(-1.96)		(-7.50)	(-5.15)
$LegalSystem_{ct-1}$		-0.0112	-0.0158		0.00422	0.0760*
Gap_{isct-1}			0.301***	0.449***	0.494***	0.474***
			(43.05)	(20.03)	(23.57)	(23.74)
$Periphery_c$						0.163**
						(2.77)
Estimator	Within	Within	Within	System GMM	System GMM	System GMM
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	797109	797109	797109	797109	797109	797109
R^2	0.089	0.089	0.159			

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Clustered Standard Errors at the country and 2 digit industry level. All regressions are weighted by the initial sample share and include firm age and size (turnover and employment) controls.

E Model Validation

E.1 Summary statistics

Table 7: Number of observations per country (all years)

Country	No.	%
Austria	10,188	0.9
Belgium	58,397	5.0
France	160,707	13.8
Germany	109,340	9.4
Italy	427,129	36.8
Netherlands	5,664	0.5
Portugal	113,589	9.8
Spain	275,731	23.8
Total	1,160,745	100.0

Notes: Period from 2009 to 2018. Firms from industry sectors with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the NACE Rev. 2 system.

Table 8: Frontier and Laggard firms per country - Year 2009

Country	**Laggard firms**		**Frontier firms**		**Total**	
	No.	%	No.	%	No.	%
Austria	40	90.9	4	9.1	44	100.0
Belgium	7,762	90.1	855	9.9	8,617	100.0
France	23,260	97.2	675	2.8	23,935	100.0
Germany	19,825	95.2	994	4.8	20,819	100.0
Italy	30,216	96.5	1,100	3.5	31,316	100.0
Netherlands	2,058	58.2	1,480	41.8	3,538	100.0
Portugal	17,363	99.3	122	0.7	17,485	100.0
Spain	32,227	98.4	508	1.6	32,735	100.0
Total	132,751	95.9	5,738	4.1	138,489	100.0

Notes: Firms from industry sectors with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the NACE Rev. 2 system. Frontier firms are defined as the top 5% of the Multi-factor productivity distribution.

Table 9: Frontier and Laggard firms per country - Year 2018

Country	**Laggard firms**		**Frontier firms**		**Total**	
	No.	%	No.	%	No.	%
Austria	980	77.4	286	22.6	1,266	100.0
Belgium	4,623	81.8	1,030	18.2	5,653	100.0
France	7,834	93.1	584	6.9	8,418	100.0
Germany	3,142	85.0	555	15.0	3,697	100.0
Italy	45,421	95.4	2,177	4.6	47,598	100.0
Netherlands	51	34.7	96	65.3	147	100.0
Portugal	10,089	99.0	105	1.0	10,194	100.0
Spain	26,978	96.8	905	3.2	27,883	100.0
Total	99,118	94.5	5,738	5.5	104,856	100.0

Notes: Firms from industry sectors with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the NACE Rev. 2 system. Frontier firms are defined as the top 5% of the Multi-factor productivity distribution.

Table 10: Summary Statistics for Eurozone firms (2018) - Frontier defined by Labour Productivity (Value Added per worker)

	Manufacturing							Services						
	Laggard Firms			Frontier Firms			Gap	Laggard Firms			Frontier Firms			Gap
Variables	Mean	Std. Dev.	N	Mean	Stand. Dev.	N		Mean	Std. Dev.	N	Mean	Std. Dev.	N	
Productivity	10.9	0.5	34752	12.1	0.4	2012	1.2***	10.7	0.6	42028	12.1	0.7	2309	1.4***
Employees	161.3	1115.4	34752	280.3	2521.4	2012	119*	338.6	4731.4	42028	341.9	3232.8	2309	3.3
Capital-labour ratio	61.0	89.5	34752	159.8	274.4	2012	98.8***	42.3	91.2	42028	323.8	926.0	2309	281.5***
Investment	2154.7	21331.6	34752	11817.9	184471.6	2012	9663.2*	3920.0	129956.9	42028	26113.0	269592.9	2309	22193.0***
Turnover	46.5	366.4	34752	269.4	2684.5	2012	222.9***	69.8	807.1	42028	369.8	2461.5	2309	300***
Markup (log)	-0.0	0.3	34730	-0.0	0.4	2011	0.0	0.0	0.4	42027	-0.1	0.8	2309	-0.1***
Wages	41.4	15.1	34752	63.7	22.9	2012	22.3***	36.4	18.5	42028	107.1	902.4	2309	70.7***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Averages are weighted by the sample share of each country. The sample contain firms from industry sectors with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the NACE Rev. 2 system. Frontier firms are defined as the top 5% of the Multi-factor productivity distribution. Productivity and Mark-ups are defined in logs. Wages, Investment and the Capital labour ratio are in thousands of 2015 euros. Turnover is in millions of 2015 euros.

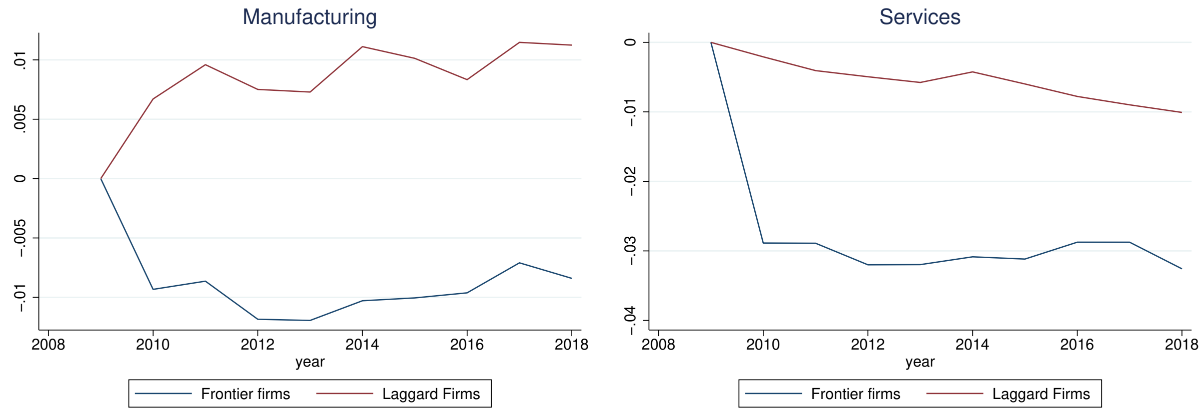
Table 11: Summary Statistics for Eurozone firms (2018) - Frontier defined by Multi-factor Productivity

	Manufacturing							Services						
	Laggard Firms			Frontier Firms			Gap	Laggard Firms			Frontier Firms			Gap
Variables	Mean	Std. Dev.	N	Mean	Stand. Dev.	N		Mean	Std. Dev.	N	Mean	Std. Dev.	N	
Productivity	10.9	0.5	34730	12.0	0.5	2034	1.1***	10.7	0.6	41948	11.9	0.8	2389	1.2***
Employees	132.0	816.4	34730	776.1	3964.2	2034	644.1***	237.7	2124.8	41948	2145.7	18081.0	2389	1908***
Capital-labour ratio	63.2	95.1	34730	118.7	250.1	2034	55.5***	45.9	115.5	41948	247.2	875.3	2389	201.3***
Investment	1663.3	16482.6	34730	19995.3	190418.6	2034	18332***	2130.9	24277.7	41948	57173.9	599401.5	2389	55043.0***
Turnover	35.3	272.8	34730	455.0	2822.4	2034	419.7***	48.6	336.0	41948	736.0	3885.4	2389	687.4***
Markup (log)	-0.0	0.3	34708	-0.1	0.4	2033	-0.1***	0.0	0.4	41947	-0.1	0.7	2389	-0.1***
Wages	41.3	15.0	34730	65.4	22.3	2034	24.1***	36.4	18.5	41948	104.8	883.7	2389	68.4***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Averages are weighted by the sample share of each country. The sample contain firms with at least 20 employees from industry sectors with 2 digit codes between 5 and 82, excluding codes from 64 to 66, in the NACE Rev. 2 system. Frontier firms are defined as the top 5% of the Multi-factor productivity distribution. Productivity and Mark-ups are defined in logs. Wages, Investment and the Capital labour ratio are in thousands of 2015 euros. Turnover is in millions of 2015 euros.

E.2 Productivity growth

Figure 4: Euro area - Productivity (value added per worker)



(a) Manufacturing

(b) Services

Notes: Frontier firms are defined as the top 5% of the Multi-factor productivity distribution at time t. The y-axis represents log-differences from the starting year, which has been normalized to 0.

Source: Author's calculations based on the Amadeus and Sabi databases.

Figure 5: Euro area - Multi-factor Productivity (MFR)

(a) Manufacturing Sector

(b) Services Sector

Notes: Frontier firms are defined as the top 5% of the Multi-factor productivity distribution at time t. The y-axis represents log-differences from the starting year, which has been normalized to 0.

Source: Author's calculations based on the Amadeus and Sabi databases.

Figure 6: Euro area - Capital Stock

Notes: Frontier firms are defined as the top 5% of the Multi-factor productivity distribution at time t. The y-axis represents log-differences from the starting year, which has been normalized to 0.

Source: Author's calculations based on the Amadeus and Sabi databases.

E.3 Sector

Table 12: Consequences of MFP GAP for Sectoral Productivity

	(1)	(2)	(3)
	$\Delta SectoralMFP_{st}$	$\Delta SectoralMFP_{st}$	$\Delta SectoralMFP_{st}$
$AverageGap_{st-1}$	-0.00357	-0.0315	-0.0143^{+}
	(-0.35)	(-0.77)	(-1.94)
$\delta SectoralMFP_{st-1}$		0.967***	
			(8.04)
Estimator	Pooled OLS	Within	System GMM
Year Dummies	Yes	Yes	Yes
Industry Fixed Effects	Yes	-	-
N	712036	712036	712036
R^2	0.706	0.249	

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. $\Delta SectoralMFP_{st}$ is the weighted cross country average of the Multi-factor productivity growth rate for sector s at time t. $AverageGap_{st-1}$ is the average gap between frontier and laggard firms across countries for sector s at time t. All averages are weighted by the share of each country in the initial sample. Standard errors are clustered at the industry level. Sample period from 2009 to 2018, including only firms with at least 20 employees.

E.4 Catch-up with the frontier

A possible concern for the identification of the coefficient on gap_{isct-1} in equation 6, is that MFP_{isct-1}. To correct for possible bias arising from this issue, column (3) and (4) in table 13 present the results of the Arellano-Bond estimation with gap_{isct-1} as a potentially endogenous variable.

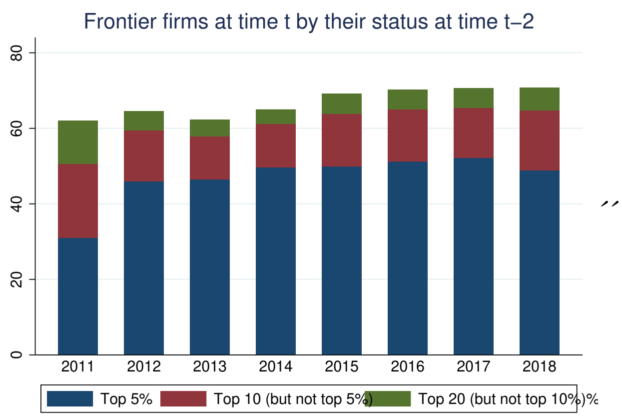
Table 13: Convergence at the firm level

	(1)	(2)	(3)	(4)
	ΔMFP_{isct}	ΔMFP_{isct}	ΔMFP_{isct}	ΔMFP_{isct}
ΔMFP_{Fsct}	0.0464***	0.0464***	0.0164***	0.0121***
	(27.14)	(27.14)	(10.06)	(8.39)
Gap_{st-1} (Base Effect)	0.0590***	0.0590***	0.0267***	0.00555***
	(65.81)	(65.81)	(10.51)	(11.45)
Gap_{st-1}*2013-2015	0.00313***	0.00313***	-0.0198***	0.00125**
	(8.33)	(8.33)	(-8.25)	(2.73)
Gap_{st-1}*2016-2018	0.00329***	0.00329***	-0.0202***	0.000879+
	(5.04)	(5.04)	(-8.71)	(1.92)
$EuroAreaR_{t-1}$		0.000251		0.000520
		(0.22)		(0.23)
ΔMFP_{isct-1}			-0.161***	-0.174***
			(-28.09)	(-44.29)
Estimator	Within	Within	System GMM	System GMM
Year Dummies	Yes	Yes	Yes	Yes
N	757824	757824	600880	600880
R^2	0.336	0.336		

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sample period from 2009 to 2018, including only non-frontier firms with at least 20 employees. Clustered Standard Errors at 2 digit industry and country level. All regressions are weighted by the initial sample share and include firm age and size (turnover and employment) controls.

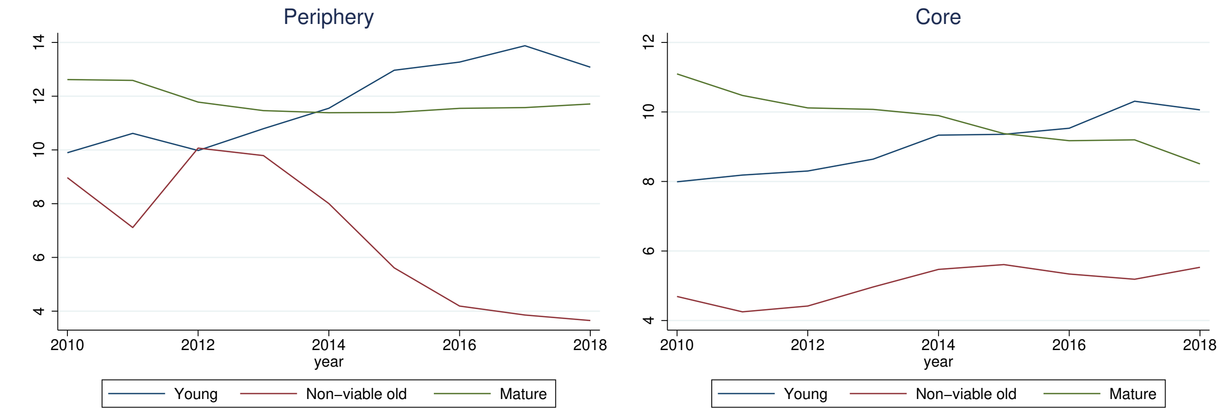
E.5 Market Dynamism

Figure 7: Leadership Persistence



Notes: Frontier firms are defined as the top 5% of the Multi-factor productivity distribution at time t.
Source: Author's calculations based on the Amadeus and Sabi databases.

Figure 8: Market Dynamism

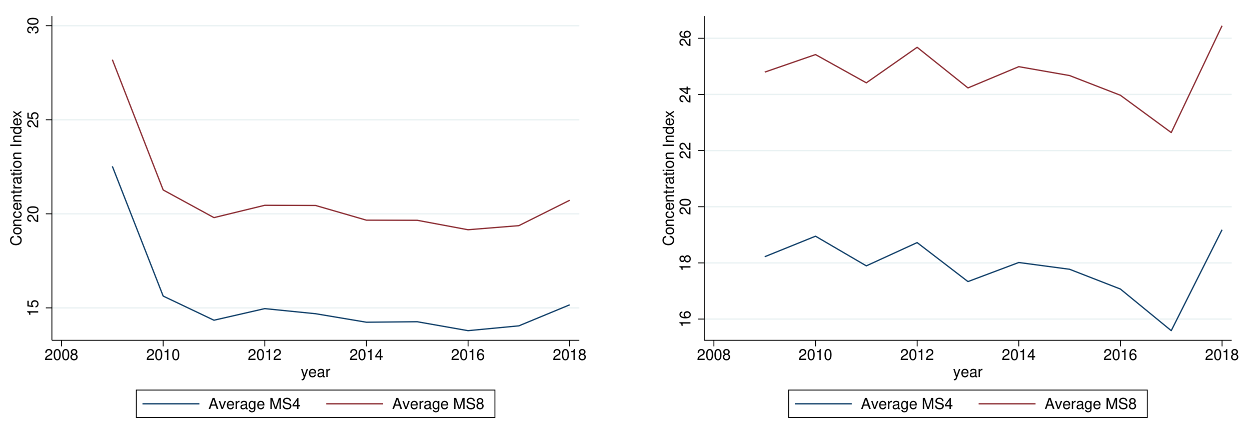


(a) Periphery (b) Core

Notes: The graph is plotted after computing the share of young firms (aged 0 - 5 years), mature firms (5 - 10 years), non-viable old firms (over 10 years and with at least two consecutive years of negative profits) and viable old firms (all the others). Periphery countries include Italy, Portugal and Spain. The group of core countries is composed by Austria, Belgium, France, Netherlands and Germany.

Source: Author's calculations based on the Amadeus and Sabi databases.

Figure 9: Concentration Index

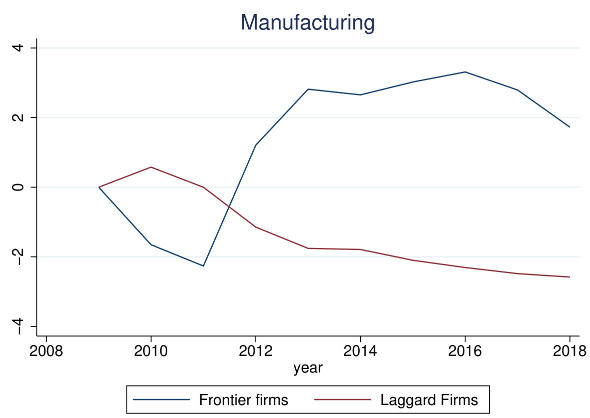


(a) Manufacturing Sector (b) Services Sector

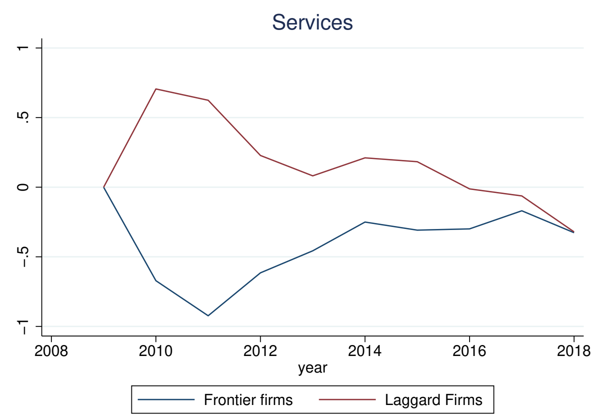
Notes: First, the market share of the top4 or top8 companies in the single market sample in each sector is computed. Each of the lines is the weighted average (by the number of firms in each 2 digit sector) of those measures for the manufacturing and for the services sector. The services sector sample does not include financial and public activities.

Source: Author's calculations based on the Amadeus and Sabi databases.

Figure 10: Mark-up evolution by type of firm and sector



(a) Manufacturing Sector



(b) Services Sector

Notes: variables are not in logs.

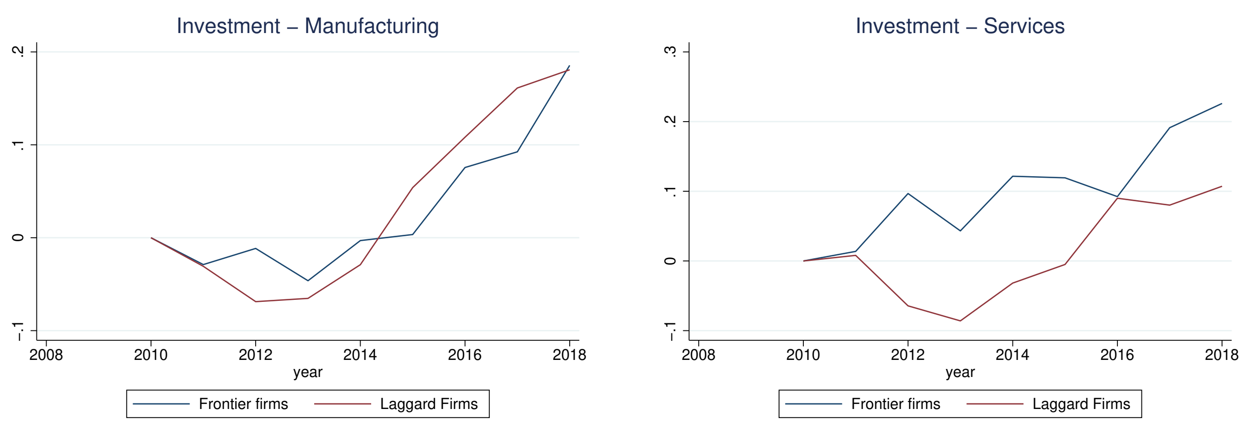
Source: Author's calculations based on the Amadeus and Sabi databases.

E.6 Investment

Running a regression between the investment ratio gap and the productivity gap might not be very meaningful as the two variables might simultaneously influence each other. For that reason, only correlations are computed. The Pearson's Correlation coefficient between the Sector Investment to Value Added Ratio Gap and Sector MFP Gap yields a value of 0.1112 with a p-value of 0.00. Thus, the two variables, even though displaying a positive relationship, do not seem to be highly correlated as one should expect.

Table 14 displays the results for the investment related regressions. Regarding robustness, the correlation between the weighted average value of the MFP for each sector and its lagged value is of 0.9134. Thus, an AR(1) model could be important to control for the persistence of the variable.

Figure 11: Investment Growth by type of firm



(a) Manufacturing Sector (b) Services Sector

Notes: Frontier firms are defined as the top 5% of the Multi-factor productivity distribution at time t. The y-axis represents the percentage increase from the starting year, which has been normalized to 0.

Source: Author's calculations based on the Amadeus and Sabi databases.

Table 14: Sectoral Investment and Investment Gap

	(1)	(2)	(3)	(4)	(5)
	$SectorInv/VA_{st}$	$SectorInv/VA_{st}$	$SectorInv/VA_{st}$	$SectorInv/VA_{st}$	$SectorInv/VA_{st}$
$AverageInv/VAGap_{st-1}$	0.306	0.280	0.280	0.126^{+}	0.126^{+}
	(0.95)	(1.40)	(1.40)	(1.69)	(1.69)
$AverageMFPGap_{st-1}$	-5.138	-18.83	-18.83	-0.962	-0.962
	(-0.96)	(-1.25)	(-1.25)	(-0.59)	(-0.59)
$EuroAreaR_{t-1}$			1.684^{+}		2.279
			(1.95)		(1.64)
$SectorInv/VA_{st-1}$				0.840^{***}	0.840^{***}
				(24.43)	(24.43)
Estimator	Pooled OLS	Within	Within	System GMM	System GMM
Year Dummies	Yes	Yes	Yes	Yes	
N	252668	625592	625592	625592	625592
R^2	0.688	0.064	0.064		

Notes: t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sample period from 2009 to 2018, including only firms with at least 20 employees. Clustered Standard Errors at the 2 digit industry level.