The ICT Revolution and Italy's Two Lost Decades*

Fabiano Schivardi
Università Bocconi, EIEF and IGIER

Tom Schmitz
Università Bocconi and IGIER

November 28, 2016

PRELIMINARY AND INCOMPLETE - PLEASE DO NOT CIRCULATE OR CITE

Abstract

While Italy grew faster than the US and Northern Europe for most of the postwar period, it has virtually stopped growing since the middle of the 1990s. The slowdown is primarily due to exceptionally low productivity growth, and we argue that an important reason behind it is the failure of Italian firms to take up the ICT revolution. This, in turn, is due to long-standing distortions in the internal organization of Italian firms, favouring family ownership, small firm size and a centralized management style. To make this point, we write a heterogeneous firm model with ICT adoption and manager hiring. In the model, a distortion for the use of managers in Italian firms leads to lower ICT adoption, both directly, as managers and ICT are complements, and indirectly, as barriers to growth for large firms lead to the survival of a larger number of small and unproductive firms which do not find it profitable to pay the fixed cost of ICT. Using microdata from surveys on the usage of ICT in firms in Italy and Germany (which we take to represent a less distorted economy), we document differents in the use of ICT and managers which are in line with the model's predictions. Eventually, the model can be used to assess how much of Italy's divergence since the middle of the 1990s can be explained by the ICT revolution, and whether ICT will continue to lead to further divergence in the future.

Keywords: Italy, Productivity slowdown, ICT adoption

JEL Codes: L23, O33

*Schivardi: Department of Finance, Università Bocconi, Via Roentgen 1, 20136 Milan, Italy, fabiano.schivardi@unibocconi.it. Schmitz: Department of Economics, Università Bocconi, Via Roentgen 1, 20136 Milan, Italy, tom.schmitz@unibocconi.it.

1 Introduction

From the end of World War 2 to the middle of the 1990s, Italy had higher or equal GDP growth rates than the United States and Northern Europe. Since then, however, Italian growth has been dismal: real GDP per capita has increased by only 3% between 1995 and 2015. This major slowdown was driven by exceptionally low productivity growth. Between 1995 and 2015, real GDP per hour worked in Italy grew by just 6%, whereas it increased by 24% in the entire Eurozone, 28% in Germany and 40% in the United States.[1] The reasons for this productivity slowdown and the ensuing twenty-year trend of ever greater divergence between Italy and other developed economies are still not well understood.[2]

In this paper, we argue that an important reason for Italy's productivity slowdown has been the failure of Italian firms to take up modern Information and Communication Technologies (ICT). Indeed, the ICT revolution has been an important driver of productivity growth in other developed countries since the mid-1990s (Fernald (2014), Gordon (2016)).[3] In Italy, however, it has made relatively little headway. In 2007, Italian firms' ICT capital per hour worked stood at roughly one third of the German and one fifth of the US level.[4] In the European Commission's 2016 "Digital Economy and Society Index", Italy ranks 15th out of 19 Eurozone countries for the integration of digital technology in firms.[5] This raises two questions: Why do Italian firms use so little ICT? And how important are differences in ICT usage to explain the overall Italian productivity gap with Northern Europe and the United States?

We explore the hypothesis that low ICT adoption in Italy is due to long-standing distortions regarding the internal organization of Italian firms, favouring family ownership, small firm size, and a centralized management style. Indeed, the literature on ICT and productivity growth has repeatedly emphasized that changes in management and organizational practice are necessary to reap the full benefits of ICT, and that ICT is more likely to be productivity-enhancing in flexible, decentralized environments (Brynjolfsson and Hitt (2000), Garicano and Heaton (2010), Bloom et al. (2012)). Thus, as ICT was not well suited to the internal organization of Italian firms, fewer of them took up the new technology, and that the ones who did did so less efficiently than their Northern European or American counterparts.

[1] Growth rates are calculated using the OECD.Stat database (available at http://stats.oecd.org, accessed on October 6, 2016). The Eurozone refers to the 19 member states in 2016, and data for the US growth refers to the period 1995-2014. Considering Total Factor Productivity (TFP) rather than GDP per hour worked yields a very similar pattern.

[2] Italy's experience is similar to that of other Southern European countries. In particular, Spanish real GDP per hour worked also increased by only 16% between 1995 and 2015, and Spanish TFP growth was even worse. Even though at first glance, the macroeconomic experience of both countries during the last two decades is very different - a continuous and slow decline in Italy, a large boom-bust cycle in Spain - they therefore appear to share some common structural characteristics.

[3] In 1987, Robert Solow famously complained that "*you can see the computer age everywhere, except in the productivity statistics*" (Solow (1987)). However, Fernald (2014) and Gordon (2016) show that around ten years later, ICT caused productivity growth in the United States to accelerate substantially for about a decade (1994-2004). They also note that growth has slowed down since, and Gordon claims that it will remain low in the foreseeable future. Yet, even the lower growth rate of US productivity between 2005 and 2015 is substantially higher than the Italian one in that same time period. Also, other authors have been more optimistic about the productivity-enhancing capacities of ICT in the future (Brynjolfsson and McAfee (2014)).

[4] These figures are taken from the EU KLEMS database, where 2007 is the last available year (see Section 2 for details).

[5] Luxembourg, Greece, Latvia and Estonia are ranked lower. See https://ec.europa.eu/digital-single-market/en/desi.

To formally analyze the effect of management distortions on ICT adoption, we write a heterogeneous-firm model with technology adoption and management choices, building on a closed-economy version of the Melitz (2003) framework. In our model, firms can produce differentiated goods with an exogenous, randomly drawn baseline productivity, but they can also increase output per production worker by hiring managers and by adopting ICT. Importantly, these two actions are complementary: firms with more managers get a larger productivity increase from ICT, and firms using ICT get a larger productivity increase from managers. The model predicts that manager hiring and ICT adoption are increasing in the exogenous baseline productivity draw (and therefore, in firm size), so that the firms with the highest productivity draws both hire managers and use ICT. The firms with the lowest productivity draws instead exit the market, as there is also a fixed cost of production which they do not find worth paying.

We use the model to compare two economies which are equal except for one parameter governing the efficiency of the delegation process between the firm owner and managers. Following Akcigit et al. (2016), these differences in "delegation efficiency" are modeled in a reduced-form way as differences in manager productivity.[6] In the economy with a lower delegation efficiency, which we take to represent Italy, firms hire less managers. As managers and ICT are complements, this explains that firms are also less likely to adopt ICT. Moreover, as the Italian firms with the highest productivity draws hire less managers, they remain smaller than they would be in an undistorted economy, allowing more small, low-productivity firms to survive in equilibrium. Thus, the model highlights two reasons for lower ICT adoption in Italy. First, conditional on productivity, some firms with intermediate productivity draws, which would have adopted ICT in an undistorted economy, do not do so in Italy, as they do not have enough or good enough managers. Second, Italy has a larger share of small and unproductive firms which do not find it profitable to pay the fixed cost of ICT.

Comparing an equilibrium with ICT to an equilibrium without ICT, we show that ICT generally increases productivity and income differences between Italy and an undistorted economy. This is because less Italian firms adopt productivity-enhancing ICT, and because ICT decreases the market share of firms using no managers (for which there are no productivity differences between Italy and an undistorted economy) and increases the market share of firms with managers (which lower delegation efficiency makes less productive in Italy).

Finally, the model shows that as the ICT revolution progresses (that is, as the productivity enhancement due to ICT gets larger and larger), there are forces of convergence and divergence. Differences in ICT and management adoption rates between Italy and the undistorted economy eventually disappear, as all Italian firms start using ICT and hiring managers, and this would suggest convergence in national incomes.

[6] Akcigit et al. (2016) show that these may also capture differences in efficiency of the judiciary system, or differences in trust towards managers. For the moment, we do not take a stand on which one of these frictions we believe to be most relevant in the Italian case.

However, the higher share of ICT and management-using firms also makes differences in delegation efficiency between the two economies more salient: they apply to an ever larger share of firms, and this suggests further divergence. In our model, this second force always dominates the first one. Thus, productivity and income differences between Italy and the undistorted economy are monotonically increasing in the productivity of ICT. However, the relationship is concave, so that relative differences eventually stabilize.

To test the model's predictions and to quantify the importance of its mechanisms, we turn to firm-level data from Eurostat's "Community survey on ICT usage and e-commerce in enterprises" for Italy and Germany. We consider Germany to represent an undistorted economy. This is a conservative choice, as Germany is far from outstanding regarding ICT usage.

Even though our model assumes that Italy and Germany differ in just one aspect, delegation efficiency, it can account for a large number of features in the data. We show that various types of ICT technologies are less used by Italian firms than by German ones, and that this is due both to differences conditional on productivity (proxied by size)[7] and to differences in the firm size distribution. These features appear to be driven by differences in firms' demand for ICT, as in our model, and not to differences in the supply of ICT, as Italian firms have actually less difficulties in filling ICT-related vacancies than German ones. Finally, we show that Italian firms also hire less managers (using their expenditures on training as a proxy for manager hiring), and that ICT has a strong effect on firm-level productivity. Eventually, we want to use the data to pin down values for some of the model's key parameters, and then use the model to assess how much of the divergence between Italy and Germany in the last twenty years is due to the ICT revolution.

The Italian productivity slowdown has been studied in several papers. The most related work to ours is Pellegrino and Zingales (2014). They assess a long list of potential causes of the slowdown, and find support for two of them. First, they argue that the greater production share of small firms inhibited a productive response to higher international competition. Second, and more importantly, they argue that "familism and cronyism" in Italian firms have made them unable to benefit from the ICT revolution. While this argument is similar to ours, we use more detailed firm-level data to provide support for it, and we propose a model to assess all its implications. In particular, the model allows us to identify, decompose and test the different margins at work in the data, and eventually, to provide a quantitative assessment of the importance of the ICT revolution as a driver for Italian divergence.[8] Indeed, the use of a model is probably our main contribution with respect to the existing literature, which is almost exclusively empirical.

[7]Moreover, as predicted by the model, adoption differences are largest for firms of intermediate sizes.

[8]This helps to clarify some important points, especially with respect to the size distribution of Italian firms. Indeed, it is often argued that the high number of small firms in Italy is a reason for its lower ICT adoption. This argument, however, is incomplete, because the size distribution of firm is not an exogenous characteristic of an economy, but an endogenous outcome. In our model, the size distribution is therefore an important channel, but not the ultimate cause of Italy's problems.

In a series of talks, Garicano (2015) also argues that management and the left-skewed size distribution in Italy (and Spain) are key to understand low rates of ICT adoption. He claims that the ultimate cause of left-skewedness could be size-dependent regulations. However, while there is evidence that size-dependent regulations are important in some countries, such as France (Garicano et al. (2013)), they do not appear to be driving the shape of the Italian firm size distribution (Schivardi and Torrini (2008)). Other studies have emphazised different explanations for the Italian productivity slowdown, citing increasing misallocation (Calligaris (2015), Calligaris et al. (2016)), implicit subsidies to low-skilled labour (Daveri and Parisi (2010)) and worsening governance (Gros (2011)). Certainly, such a long-lasting and deep phenomenon as the Italian slowdown is not monocausal, and we do not claim that the ICT revolution it its only driver. However, we provide evidence for it being an important factor.

In other related work, Bloom et al. (2012) show empirically that the subsidiaries of US multinationals in Great Britain use more ICT, and use ICT more productively than subsidiaries of multinational firms from other countries, or British firms. They interpret this as evidence that the management practices of US firms are more suited to an efficient use of ICT, and could explain growing divergence between Europe and the United States. Our model could speak to this more general case, too. Finally, Akcigit et al. (2016), study the effect of differences in delegation efficiency for aggregate TFP differences in India and in the United States, using an endogenous growth model, but not considering technology adoption.[9]

The remainder of the paper is structured as follows. Section 2 presents some stylized facts on the Italian productivity slowdown, the ICT revolution, and the management and size structure of Italian firms. Section 3 introduces our model, and Section 4 studies its predictions for the impact of the ICT revolution in economies with different levels of delegation efficiency. Finally, Section 5 uses firm-level data to assess the model's predictions, and eventually will seek to quantify the importance of ICT for Italian divergence.

2 Motivating evidence

2.1 Aggregate productivity growth

Figure 1 documents the Italian productivity slowdown: around the middle of the 1990s, Italian productivity growth decoupled from Northern European countries (such as Germany) and the United States. The figure uses data from the EU KLEMS database,[10] which has the advantage of reporting sectoral data and data on the investment in ICT capital, but the disadvantage of being available only until 2007.[11] However, abstracting

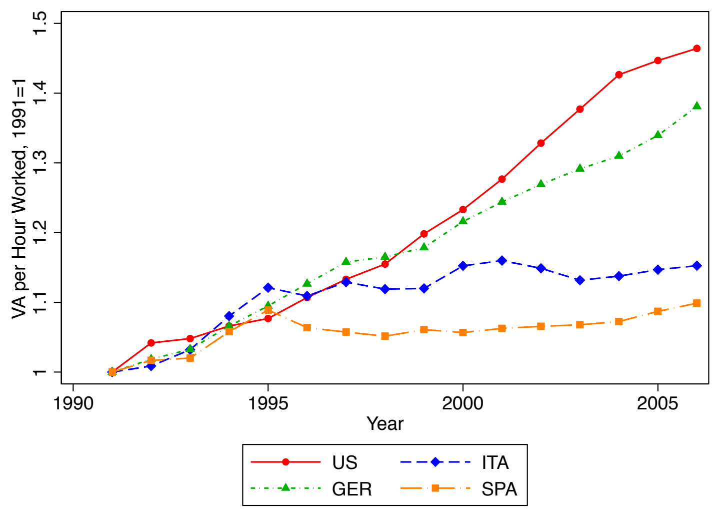
[9] Our model is also related to Bustos (2011), who shows that in a Melitz model, trade liberalizations increase the share of firms producing with advanced technologies when technology adoption and exporting are complements.

[10] For further details, see http://www.euklems.net/ and O'Mahony and Timmer (2009).

[11] We use data from 1991 (the first year of the German Unification) onwards. We may want to change this to show a more long-run picture.

from the Great Recession may also be reasonable, as cyclical factors could blur long-run productivity trends.

Figure 1: VA per Hour Worked in different countries, 1991=1



Note: We exclude the public sector, agriculture and mining. Results are very similar if we also include these sectors.

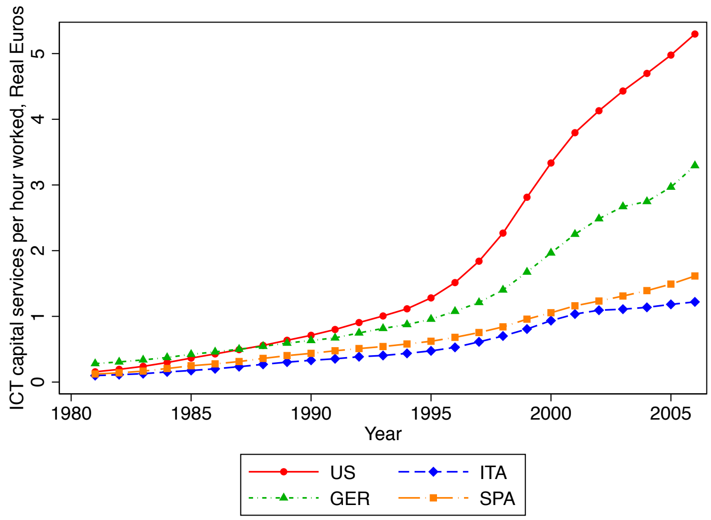
Figure 1 shows that while Italian productivity growth (measured by value added per hour worked) was in line with other developed economies until 1995, it started to stagnate after that date, while productivity kept growing in Germany and even more strongly in the United States. A similar picture emerges if we use TFP to measure productivity. Importantly, the Italian slowdown is not to to its sectoral structure: Italian productivity growth has been lower than that of Northern Europe or the United States within virtually every sector (see the Appendix, and Pellegrino and Zingales (2014)). Thus, the slowdown cannot be due to Italy being specialized in the "wrong" sectors, but must be due to more general factors applying to all parts of the economy.

2.2 The ICT revolution

Italy's productivity slowdown started around the same time as the ICT revolution (that is, firms' large-scale adoption of ICT) increased productivity growth in most developed economies. Figure 2 shows, however, that this ICT revolution was limited in Italy. It reports ICT capital services per hours worked, measured in real 1995 euros, again obtained from the EU KLEMS database.[12]

[12]To convert US $ in euros, we have used the average exchange rate between the dollar and the euro between 1999 (first year of existence of the euro) and 2007. Given that we are interested in the time series evolution more than in the cross country differences, the conclusions we draw are robust to the conversion method. Moreover, for this series we cannot exclude the public sector, agriculture and mining.

Figure 2: ICT Capital Services per hour worked, Real Euros



In the US, the frontier country, the contribution of ICT capital services to production accelerates exactly around the mid nineties, in correspondence with the increase in productivity growth documented in Figure 1: ICT capital services per hour worked went from around one euro in 1991 to 5 euros in 2007. There is a consensus that these two trends are linked, and that ICT caused the increase in productivity growth (Fernald (2014), Gordon (2016)).[13] The increase has been lower but still substantial in Germany, while it was much more modest in Italy: in 2007, ICT capital services per hour worked in Italy were around one euro (against three for Germany).

So, given the fact that ICT boosted productivity growth in the frontier economies, and Italy appears to have had little ICT penetration, it is reasonable to suppose that the Italian slowdown can be explained at least partially by low ICT adoption. The next section discusses some structural features of the Italian economy which may have caused this low ICT adoption.

2.3 Delegation efficiency and firm size

Italy differs from Northern Europe and the United States in many aspects that might account for lower ICT penetration. For instance, the educational attainment of the working population is lower, and infrastructure is less developed. In this paper, however, we focus on one specific factor which can explain low ICT demand from Italian firms, namely their internal organization. In the model, we will introduce these differences as differences in managerial "delegation efficiency", captured in reduced form as a lower productivity of managers.

[13]The literature typically explains the Solow paradox, and the delay of ICT showing up in productivity statistics, with the necessity of implementing long-lasting organizational changes to fully exploit the possibilities of ICT (Brynjolfsson and Hitt (2000)). The necessity for complementary inputs to ICT will play a crucial role in our model.

Measuring delegation efficiency in the data is difficult. As a proxy, we use data from EFIGE, a database of European firms with information on the ownership and control structure for firms with at least 10 employees. Table 1, taken from Bugamelli et al. (2012), reports the share of firms controlled by a family or an individual and, within such firms, the share of firms with a CEO who is a family member and the share of firms in which all executives are family members for five European countries.[14]

Table 1: Share of firms with family ownership and control (in percentage points)

	Family owned firms	**Within firms owned firms:**	
		CEO is a family member	All executives are family members
France	80.0	62,2	25,8
Germany	89,8	84,5	28.0
Italy	85,6	83,9	66,3
Spain	83.0	79,6	35,5
United Kingdom	80,5	70,8	10,4

Source: EFIGE database (see Bugamelli et al. (2012)).

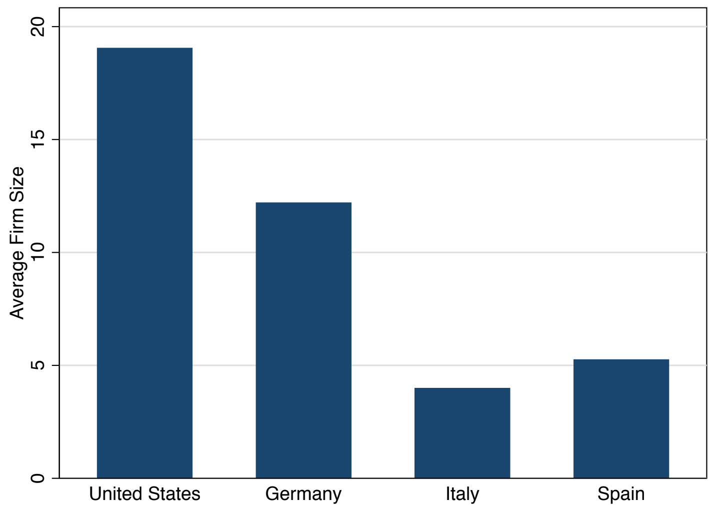
Family ownership is very common in all countries, and the majority of family-owned firms has a family CEO. However, the share of firms where all executives are family members is very heterogeneous. Italy clearly stands out in this respect: two thirds of family-owned firms are also completely family controlled, whereas this number is below 30% for Germany, France and the United Kingdom. This suggests inefficiencies in the managerial delegation process, as empirical evidence indicates that family firms without external managers tend to perform worse in measures of good management (Bloom et al. (2014)).

A related feature of Italy's economic structure is the prevalence of small firms. Figure 3 reports average firm size, measured by the number of employees, for Italy, the United States and Germany. Average firm size is largest in the United States. However, what stands out is that the average Italian firm has approximately one fifth of the employment of the average US firm, and one third of that of the average German firm. As shown by Pagano and Schivardi (2003), these differences are again not due to sectoral composition: they persist within two-digit sectors, pointing to some more general country characteristic determining this pattern.

In the next two sections, we present and study a simple static heterogeneous-firm model, building on Melitz (2003), to study how differences in average firm size, differences in ICT penetration and differences in the share of firms with non-family managers can be generated by one common cause, differences in managerial delegation efficiency, and to analyze the implications of this for Italy's relative economic performance.

[14] Ownership and control structure are self-reported.

Figure 3: Average firm size



3 Model

3.1 Assumptions

Agents and preferences The economy is populated by a mass L of workers who have CES preferences over an (endogenously determined) mass M of differentiated final goods:

$$C = \left(\int_0^M c(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad \text{with } \varepsilon > 1. \tag{1}$$

Each worker inelastically supplies one unit of labour, and workers own all the firms in the economy.

Firms and technologies Firms can be created by paying an entry cost of f_E units of labour. A firm produces one differentiated final good i with the production function

$$y(i) = A(i)\,\varphi_N \left((\varphi_L l(i))^{\frac{\sigma-1}{\sigma}} + (\mathbb{1}_M \varphi_M m(i))^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \quad \text{with } \sigma > 1, \tag{2}$$

where $A(i)$ is an exogenous productivity draw which firm i takes from a cumulative distribution function G after paying the entry cost. After learning its productivity, the firm can decide to produce with the technology defined in Equation (2), in which case it must pay a fixed cost of f units of labour, or to exit.

A firm produces output using at most two inputs, production labour $l(i)$ and management $m(i)$. Both managers and workers are paid the same wage w,[15] but for hiring managers, there is an additional fixed cost

[15] It is now tempting to reintroduce two types of labour and a skill premium into the model, although this is not our main focus.

of f_M units of labour, which explains that not all firms hire managers in equilibrium. The firm's decision with respect to manager use is described by the indicator variable $\mathbb{1}_M$. Firms which hire managers combine management and production labour with a CES production function, while firms which do not hire managers have just a linear production function in production labour.[16]

The terms in φ capture the three different types of technological change which can occur in this model. Technological change that occurs through increases in φ_N is Hicks-neutral, while increases in φ_L are production labour-augmenting, and increases in φ_M management-augmenting. Following the ICT literature (Brynjolfsson and Hitt (2000), Garicano and Heaton (2010)), we model ICT as management-augmenting technological change. This is crucial for all our results, as it implies that inefficiencies in management spill over to ICT adoption. Precisely, we assume that

$$\varphi_M = \xi \left(1 + \mathbb{1}_{ICT} \varphi_{ICT}\right),$$

where $\mathbb{1}_{ICT}$ is an indicator function describing the firm's decision to adopt ICT, and φ_{ICT} is a positive constant which captures the productivity increase triggered by this decision. ICT adoption has a fixed cost of f_{ICT} units of labour. Finally, ξ is a positive parameter capturing managerial efficiency. This is the model's most important parameter. Indeed, in all of our analysis, we compare two economies (called Italy and Germany) which are completely identical, except for the fact that Italy has a lower value of ξ.

How should these differences in ξ be interpreted? In a similar setup, Akcigit et al. (2016) argue that manager productivity can capture in a reduced-form way "*the net [...] managerial services [provided] through delegation*", and propose a simple microfoundation for this. Thus, differences in ξ between Italy and Germany could be due to differences in the human capital of managers, differences in the contractual environment, cultural factors such as trust or social norms.

The ICT revolution can be modeled as a drop in f_{ICT}, an increase in φ_{ICT}, or as a combination of the two. We focus on the effects of an increase in φ_{ICT}, but most results do not depend on this.

It may be useful to note that the production function can be rewritten as

$$y\left(i\right) = A\left(i\right) \varphi_N \left(1 + \left(\mathbb{1}_M \frac{\varphi_M m\left(i\right)}{\varphi_L l\left(i\right)}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \varphi_L l\left(i\right),$$

which shows that, as in the previous draft, management and ICT adoption increase output per production worker.

This completes the model's assumptions. In the next section, we characterize its solution.

[16] From Equation (2), the production function of a firm which does not hire managers is just $y\left(i\right) = A\left(i\right) \varphi_N \varphi_L l\left(i\right)$. Note the importance of assuming $\sigma > 1$. With a Cobb-Douglas production function, for instance, management would become an essential input, and firms without management could not produce.

3.2 Solution

The "life cycle" of a firm has three sequential steps.

1. Pay the entry cost, and draw a productivity from the distribution G.

2. Decide whether to remain in the market, to hire managers, and to use ICT.

3. Decide on the price to charge (and therefore on the quantity to produce).

We solve this problem by backward induction, that is, by proceding from the last stage to the first.

3.2.1 Demand and price setting

Normalizing the CES price index P to 1, demand for any variety i is given by

$$c\left(i\right) = p\left(i\right)^{-\varepsilon} C. \tag{3}$$

This implies that firms optimally choose to set a constant mark-up $\frac{\varepsilon}{\varepsilon-1}$ over their marginal cost. Marginal costs depend on firms' exogenous productivity draw, and on whether they use managers or not. For a firm which does not hire managers, the marginal cost of production is $\frac{w}{A\varphi_N\varphi_L}$, and therefore, profits are[17]

$$\pi_{\text{NoMan}}\left(A\right) = \left(A\varphi_N\varphi_L\right)^{\varepsilon-1} B - fw, \tag{4}$$

where $B \equiv \frac{1}{\varepsilon-1}\left(\frac{\varepsilon}{\varepsilon-1}\right)^{-\varepsilon} w^{1-\varepsilon}C$.

Instead, to determine the marginal cost of a firm which hires managers, we first have to determine optimal input choices. The firm's cost minimization problem yields

$$\frac{m}{l} = \left(\frac{\varphi_M}{\varphi_L}\right)^{\sigma-1}.$$

With this, one can show that the marginal cost of production is $\frac{w}{A\varphi_N\varphi_L\widetilde{\xi}}$, where $\widetilde{\xi} = \left(1+\left(\frac{\varphi_M}{\varphi_L}\right)^{\sigma-1}\right)^{\frac{1}{\sigma-1}}$, a number larger than 1. Thus, firm which use managers have a lower marginal cost, but they also need to pay the management fixed cost. Their profits are

$$\pi_{\text{Man}}\left(A\right) = \left(A\varphi_N\varphi_L\widetilde{\xi}\right)^{\varepsilon-1} B - \left(f + f_M + \mathbb{1}_{ICT} f_{ICT}\right) w. \tag{5}$$

[17] To simplify notation, from now on we drop the firm index i whenever this does not cause confusion.

3.2.2 Production, managers, and ICT

Next, consider a firm which has learned its productivity draw A, and needs to decide on whether to produce or not, and whether to use management and ICT. Obviously, the firm chooses the option offering the highest profits. While the profits from exiting the market are 0 (abstracting from the sunk entry cost), the profits of the firms' other options are given in Table 2 below. As ICT is a management-augmenting technology, it would never be optimal for a firm to adopt it without hiring managers, so we abstract from this option.

Table 2: Profits for different choices

Choice		Profits
No man.	$\pi_{\text{NoMan}}(A)$	$= (A\varphi_N\varphi_L)^{\varepsilon-1} B - fw$
Man., no ICT	$\pi_{\text{Man,NoICT}}(A)$	$= \left(A\varphi_N\varphi_L\widetilde{\xi}_{\text{NoICT}}\right)^{\varepsilon-1} B - (f + f_M)\, w$
Man., ICT	$\pi_{\text{Man, ICT}}(A)$	$= \left(A\varphi_N\varphi_L\widetilde{\xi}_{\text{ICT}}\right)^{\varepsilon-1} B - (f + f_M + f_{ICT})\, w$

Note: We denote $\widetilde{\xi}_{\text{NoICT}} \equiv \left(1 + \left(\frac{\xi}{\varphi_L}\right)^{\sigma-1}\right)^{\frac{1}{\sigma-1}}$ and $\widetilde{\xi}_{\text{ICT}} \equiv \left(1 + \left(\frac{(1+\varphi_{ICT})\xi}{\varphi_L}\right)^{\sigma-1}\right)^{\frac{1}{\sigma-1}}$.

Table 2 shows that firms' decisions between their different options only depend on one firm-specific variable, the productivity draw A. Due to fixed costs, the firms with the lowest productivity draws decide to exit. The firms with the highest productivity draws, instead, will use both managers and ICT, allowing them to get the lowest possible marginal costs.

More generally, it is easy to show that firms' decisions for production, manager use and ICT adoption are characterized by cut-off rules. Firms with productivity draws above a cut-off level A_E^* decide to produce, while firms with productivity draws below this level exit the market. Likewise, there are cut-off levels A_M^* for manager use and A_{ICT}^* for ICT adoption, holding

$$A_E^* \leq A_M^* \leq A_{ICT}^*.$$

Depending on parameter values, these cut-offs can completely or partially coincide. In the main text, we focus on the empirically most relevant case in which $A_E^* < A_M^* < A_{ICT}^*$. Proposition 1 states under which parameter conditions this configuration occurs, and states the values for the cut-offs. The Appendix contains the model's solution for all other possible configurations.

Proposition 1. *Consider a firm which has drawn a productivity A. Then, decisions of this firm are then* *pinned down by the three cut-off productivity levels A_E^*, A_M^* and A_{ICT}^*. When*

$$\left(\widetilde{\xi}_{NoICT}^{\varepsilon-1}-1\right)f<f_M<\frac{\widetilde{\xi}_{NoICT}^{\varepsilon-1}-1}{\widetilde{\xi}_{ICT}^{\varepsilon-1}-\widetilde{\xi}_{NoICT}^{\varepsilon-1}}f_{ICT},$$

these cut-offs hold $A_E^*<A_M^*<A_{ICT}^*$, and are given by

$$A_E^*=\frac{1}{\varphi_N\varphi_L}\left(\frac{f}{\frac{B}{w}}\right)^{\frac{1}{\varepsilon-1}},$$

$$A_M^*=\frac{1}{\varphi_N\varphi_L}\left(\frac{f_M}{\left(\widetilde{\xi}_{NoICT}^{\varepsilon-1}-1\right)\frac{B}{w}}\right)^{\frac{1}{\varepsilon-1}},$$

$$A_{ICT}^*=\frac{1}{\varphi_N\varphi_L}\left(\frac{f_{ICT}}{\left(\widetilde{\xi}_{ICT}^{\varepsilon-1}-\widetilde{\xi}_{NoICT}^{\varepsilon-1}\right)\frac{B}{w}}\right)^{\frac{1}{\varepsilon-1}}$$

Proof. See Appendix. □

Intuitively, this case occurs when the fixed cost of management f_M is in an intermediate range: sufficiently large such that not all producing firms are willing to pay it, but sufficiently low that some firms which do not adopt ICT want to pay it. Note that all cut-offs depend only on one endogenous variable, $\frac{B}{w}$, and that their relative values (the ratios $\frac{A_{ICT}^*}{A_M^*}$, $\frac{A_{ICT}^*}{A_E^*}$, etc.) are fully pinned down by parameter values.

3.2.3 Free entry

For firms to be created in equilibrium, it must be that entry cost equals the expected profit from firm creation, that is,

$$\begin{aligned} wf_E = & \int_{A_E^*}^{A_M^*}\left(\left(A\varphi_N\varphi_L\right)^{\varepsilon-1}B-fw\right)dG\left(A\right)\ +\int_{A_M^*}^{A_{ICT}^*}\left(\left(A\varphi_N\varphi_L\widetilde{\xi}_{\text{NoICT}}\right)^{\varepsilon-1}B-\left(f+f_M\right)w\right)dG\left(A\right) \\ & +\int_{A_{ICT}^*}^{+\infty}\left(\left(A\varphi_N\varphi_L\widetilde{\xi}_{\text{ICT}}\right)^{\varepsilon-1}B-\left(f+f_M+f_{ICT}\right)w\right)dG\left(A\right) \end{aligned} \tag{6}$$

Dividing both sides by the wage and rearranging gives

$$\begin{aligned} f_E = & \left(\varphi_N\varphi_L\right)^{\varepsilon-1}\frac{B}{w}\left(\int_{A_E^*}^{+\infty}A^{\varepsilon-1}dG\left(A\right)\ +\left(\widetilde{\xi}_{\text{NoICT}}^{\varepsilon-1}-1\right)\int_{A_M^*}^{+\infty}A^{\varepsilon-1}dG\left(A\right)+\left(\widetilde{\xi}_{\text{ICT}}^{\varepsilon-1}-\widetilde{\xi}_{\text{NoICT}}^{\varepsilon-1}\right)\int_{A_{ICT}^*}^{+\infty}A^{\varepsilon-1}dG\left(A\right)\right) \\ & -f\left(1-G\left(A_E^*\right)\right)-f_M\left(1-G\left(A_M^*\right)\right)-f_{ICT}\left(1-G\left(A_{ICT}^*\right)\right) \end{aligned} \tag{7}$$

Substituting in the definitions of the cut-offs A_E^*, A_M^* and A_{ICT}^* given in Proposition 1, Equation (7) becomes an equation in just one variable, $\frac{B}{w}$. As shown in the Appendix, this equation admits a unique solution. By finding this solution, we can determine the cut-off levels A_E^*, A_M^* and A_{ICT}^*.

3.2.4 Wages and the mass of firms

All workers earn the same wage w. Furthermore, as there are no net profits (because of free entry), aggregate income and consumption is just given by $C = wL$. Using the expression for the auxiliary variable B gives

$$w = \left(\frac{L}{\varepsilon - 1} \left(\frac{\varepsilon}{\varepsilon - 1} \right)^{-\varepsilon} \frac{1}{\frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}. \tag{8}$$

Finally, we need to determine the equilibrium mass of producing firms, M, and the mass of firms paying the entry cost, M_E. These two masses are related by

$$M = (1 - G(A_E^*)) M_E.$$

M_E can be determined using the labour market clearing condition. The fixed labour supply of the economy, L, is used for six different uses: the four fixed costs (for entry, production, management and ICT) and the two occupations, production labour and management. Table 3 lists labour demand for different uses.

Table 3: Labour demands

Occupation	Mass
Entry costs	$M_E f_E$
Production fixed costs	$M_E (1 - G(A_E^*)) f$
Management fixed costs	$M_E (1 - G(A_M^*)) f_M$
ICT	$M_E (1 - G(A_{ICT}^*)) f_{ICT}$
Production workers and managers	$(\varepsilon - 1) M_E (\varphi_N \varphi_L)^{\varepsilon - 1} \frac{B}{w} \left[\int_{A_E^*}^{+\infty} A^{\varepsilon-1} dG(A) + \left(\widetilde{\xi}_{\text{NoICT}}^{\varepsilon-1} - 1 \right) \int_{A_M^*}^{+\infty} A^{\varepsilon-1} dG(A) + \left(\widetilde{\xi}_{\text{ICT}}^{\varepsilon-1} - \widetilde{\xi}_{\text{NoICT}}^{\varepsilon-1} \right) \int_{A_{ICT}^*}^{+\infty} A^{\varepsilon-1} dG(A) \right]$

Note: Further details are provided in the Appendix.

Imposing labour market clearing, and using the free-entry condition, Equation (7) gives

$$M_E = \frac{L}{\varepsilon \left(f_E + f \left(1 - G\left(A_E^*\right)\right) + f_M \left(1 - G\left(A_M^*\right)\right) + f_{ICT} \left(1 - G\left(A_{ICT}^*\right)\right)\right)}. \tag{9}$$

3.3 A special case with an analytical solution

As in Chaney (2008), our model has an analytical solution if productivity follows a Pareto distribution. Given that this is also considered an empirically successful choice (see, for instance, Melitz and Redding (2014)), we assume from now on that A follows a Pareto distribution with minimum value 1 and shape parameter k, so that $G(A) = 1 - A^{-k}$. We impose $k > \varepsilon - 1$, which is necessary to ensure that expected profits are finite. With this distribution, the entry cut-off is[18]

$$A_E^* = \left(\frac{\left(\frac{\varepsilon - 1}{k - (\varepsilon - 1)}\right) \left(f + \left(\frac{A_E^*}{A_M^*}\right)^k f_M + \left(\frac{A_E^*}{A_{ICT}^*}\right)^k f_{ICT} \right)}{f_E} \right)^{\frac{1}{k}}. \tag{10}$$

As the ratios A_E^*/A_M^* and A_E^*/A_{ICT}^* are pinned down by parameters, Equation (10) directly gives the equilibrium value of A_E^*. From this, we can deduce A_M^*, A_{ICT}^*, and wages. Furthermore, we can show that the mass of entering firms is given by

$$M_E = \frac{(\varepsilon - 1) L}{\varepsilon f_E k}. \tag{11}$$

Thus, the mass of entering firms does not depend neither on delegation efficiency ξ, nor on any of the productivity parameters φ.

4 Delegation efficiency and the ICT Revolution

We are now ready to analyse the main implications of the model. To do so, we assume that Italy and Germany are two identical economies, which are only differentiated by the fact that Italian delegation efficiency is lower: $\xi_I < \xi_D$.[19]

[18] Interestingly enough, this formula does not only hold in the configuration described by Proposition 1, but always. The same thing in true with the formula for the mass of entering firms.

[19] We also consider a version of the model in there are no differences in ξ, but instead, Italian firms face a higher fixed cost f_M for creating an organization structure compatible with managers. In the Appendix (missing), we show that many results from that model are similar to the ones presented here, but there are also a number of counterfactual implications (such as, for instance, that Italy should have a higher average firm size than Germany). This suggests that even though there may be differences in the fixed costs of management between countries, differences in the efficiency of every single manager (persisting even once the fixed cost has been paid) are more relevant to explain cross-country differences.

4.1 Italy and Germany before the ICT revolution

To characterize the initial situation of the two economies, we start by considering a case in which there is no ICT, that is, $\varphi_{ICT} = 0$. All proofs refer to the case described in Proposition 1, where $A^*_E < A^*_M < A^*_{ICT}$. Prior to the ICT revolution, Italy and Germany are characterized by a line of differences.

- In Italy, real income per capita is lower than in Germany.
- In Italy, firms which hire managers choose a lower ratio of managers to production workers. Furthermore, the percentage of firms hiring managers is lower in Italy, and, Italian firms need a higher productivity draw to start hiring managers (that is, $A^*_{M,I} > A^*_{M,D}$).
- In Italy, selection on productivity is less harsh: a larger percentage of firms paying the entry cost start to produce (that is, $A^*_{E,I} < A^*_{E,D}$,).
- In Italy, there is a larger mass of firms M.
- In Italy, a smaller percentage of the overall workforce works as managers.

As argued in the previous section, the real income of a country depends positively on the mass of varieties produced in the country, and on the average productivity with which these varieties are produced. On the first dimension, Italy has actually an advantage over Germany, as Italian consumers are offered a greater variety of differentiated goods. Italy has also a larger mass of production workers, which, all else equal, should lead to larger production. However, Italy's aggregate productivity (both TFP and output per production worker) is lower than Germany's. Indeed, conditional on the exogenous productivity draw, Italian firms are less likely to hire managers, and if they do, their managers are less efficient than the German ones. These two factors explain that firms with the same, relatively high productivity draws will achieve a lower output per production worker in Italy than in Germany. As these firms cannot expand as much in Italy than in Germany, they capture a lower share of aggregate demand, and this allows more low-productivity firms to remain in the market, further depressing aggregate productivity.

4.2 The effect of the ICT revolution

Now, we introduce the ICT revolution. To do so, we compare the solution of the model without ICT to its solution when $\varphi_{ICT} > 0$. In this section, we analyze the effect of the ICT revolution within both countries. In the next section, we turn to studying how the ICT revolution affects cross-country differences.

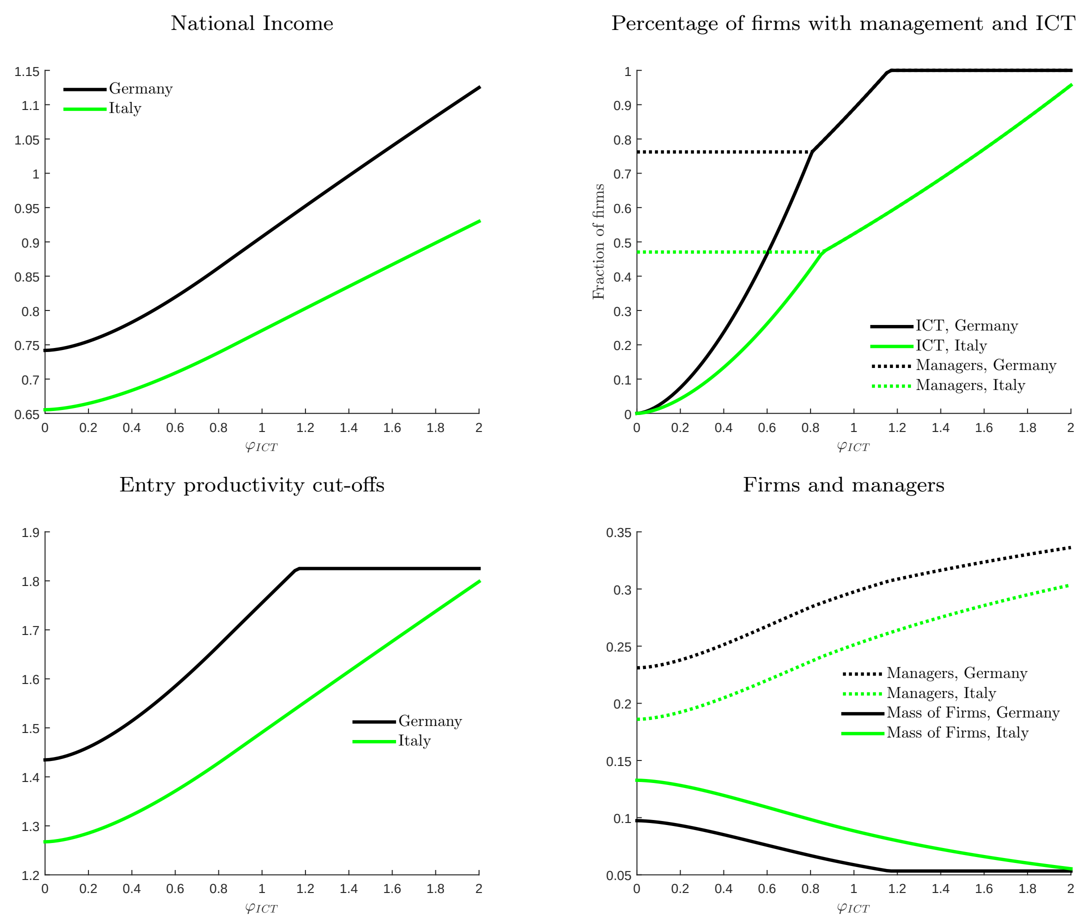
Figure 4 plots the equilibrium values of several key variables for different values of φ_{ICT}. In each graph, the value for $\varphi_{ICT} = 0$, at the left of the x-axis, corresponds to the model without ICT. Although our model is static, and there are therefore no transition dynamics, one could think of these graphs as representing a time path, showing what happens when ICT becomes more and more productive.[20]

All proofs refer to the case described in Proposition 1, where $A_E^* < A_M^* < A_{ICT}^*$. The graphs, however, are drawn without this restriction, and as ICT becomes more productive, countries transition first into an equilibrium where all firms with managament use ICT, and then into an equilibrium where all producing firms use both management and ICT.

What are the effects of the ICT revolution?

- The ICT revolution obviously increases the percentage of ICT-using firms in each country, and as ICT improves productivity, this raises each country's national income.

Figure 4: The impact of the ICT revolution



- The ICT revolution also leads to stiffer selection: the cut-off productivity level for entry A_E^* increases, and the mass of firms M decreases. Intuitively, when ICT gets more and more productive, it is most

[20]If all firms would live exactly one period, and φ_{ICT} would increase every period, then this would represent the actual time path of the model. More complex transition dynamics, allowing for incumbent firms and history dependence, are on the To Do list.

efficient to concentrate production at a few extremely productive firms, and to allocate most of the labour endowment to pay for productivity-enhancing ICT and managers at these firms. Thus, the ICT revolution increases average firm size.[21]

- ICT has a non-monotonic effect on the percentage of firms with management. For small increases in φ, this percentage does not change, but for large increases in φ, it increases. This makes sense: as long as ICT is not very productive, the only adopting firms are among the ones which already had managers before the ICT revolution. As these firms increase their hiring of managers and ICT specialists, they drive up wages and therefore discourage hiring managers at firms which before were just marginal as to that decision. In other terms, A_M^* increases, but A_E^* does so, too, and for a Pareto distribution, these two effects cancel out. This changes once ICT is so productive that all firms want to have it, and need to hire managers to use it efficiently.

- The number of managers, on the other hand, increases monotonically as the ICT revolution progresses.

The effects described in this section apply both to Germany and to Italy. However, they affect the two countries with different magnitudes, as we will analyze in the next section.

4.3 Differential effects of the ICT revolution in Italy and Germany

Figure 4 already indicates that the ICT revolution does not overturn any of the static differences between Italy and Germany: Italy continues to have a lower percentage of firms with managers, lower income per capita, less harsh selection, more firms and less managers. However, there is now another difference between the two countries: the percentage of ICT-using firms in Italy is smaller or equal than the one in Germany.[22] Lower adoption of ICT in Italy has two reasons. First, there is a direct effect: as Italian managers are less productive, and ICT is complementary to management, conditional on the productivity draw A, it is less likely that an Italian firm finds it profitable to adopt ICT. This effect applies to firms with intermediate productivity draws (between $A_{ICT,D}^*$ and $A_{ICT,I}^*$). Second, there is an indirect effect: as selection is (endogenously) less harsh in Italy, Italy has a larger number of firms with low productivity draws for whom ICT adoption does not pay off.

[21] These results depend on how the ICT revolution is modeled. If we choose to model it as a fall in f_{ICT} instead of an increase in φ_{ICT}, the response of selection and average firm size may be non-monotonic. In particular, as f_{ICT} becomes very low, selection becomes less harsh, and the number of firms increases. This is a standard response of a Melitz-type model for a decrease in fixed costs. In practice, it may depend on the sector considered whether ICT is characterized rather by falling fixed costs or increasing productivity. Indeed, in some sectors, the ICT revolution was accompanied by a decrease in average firm size (e.g. manufacturing, ICT itself), while in others, it was accompanied by an increase (e.g. retail).

[22] However, the share of ICT-using firms among firms with managers is generally higher in Italy. This is due to the fact that firms with managers in Italy are a more selected group, as only the firms with the very highest productivity have managers.

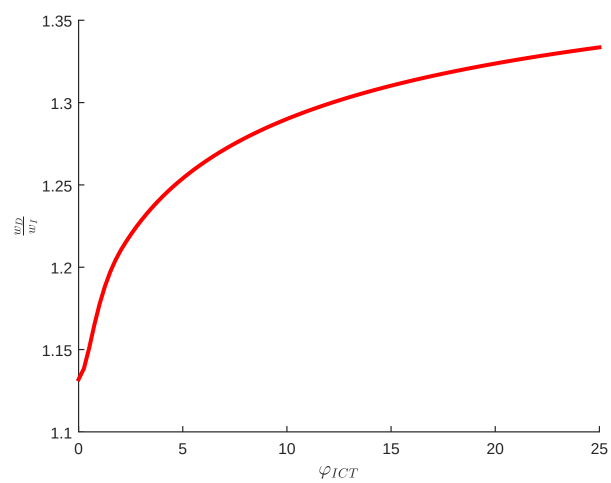
However, does the ICT revolution lead to convergence or divergence in per-capita national incomes between Italy and Germany? This is not obvious. Indeed, several forces are at work.

- **Forces of divergence.** Differential ICT adoption in both countries is the most direct and obvious driver of divergence. However, it is not the only one. Indeed, the ICT revolution makes overall production more management-intensive: there are fewer firms without managers, and those with managers hire more of them. As management gets a more and more essential production factor, the lower efficiency of Italian managers gets a more and more salient problem.

- **Forces of convergence.** For small increases in φ_{ICT}, ICT adoption rates in both countries diverge. However, when φ_{ICT} becomes large, they eventually converge again, as all firms become ICT-users. Moreover, the increasing attractiveness of ICT incentivizes more and more firms to hire managers, and the cross-country differences in the management adoption rate eventually converge, as is apparent from Figure 4.

Figure 5 indicates that in our model, divergence forces dominate, so that income differences are an increasing function of φ_{ICT}. When φ_{ICT} tends to positive infinity, income differences converge to a factor $\left(\frac{1+\xi_D^{\sigma-1}}{1+\xi_I^{\sigma-1}}\right)^{\frac{1}{\sigma-1}}$. Thus, in the limit, the strenght of our divergence mechanism depends on only two parameters, delegation efficiency and the importance of managers in production.

Figure 5: The ICT revolution, relative effects: w_D/w_I

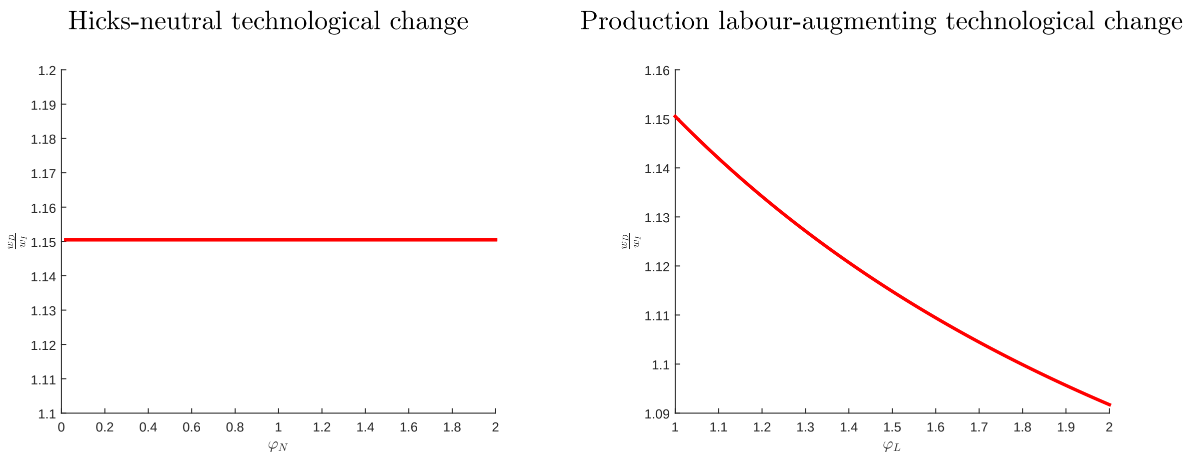


4.4 Comparisons with other types of technological change

The ICT revolution leads to divergence between Italy and Germany because it is management-augmenting, and therefore makes Italy's deficiencies with respect to management more salient.[23]

In contrast, Figure ... shows that other forms of technological change do not have the same impact. Hicks-neutral technological change (modelled as an increase in φ_N) leaves income differences exactly unchanged, as it does not interact with any selection margins (it affects, for instance, neither the mass of firms, nor the percentage of managment or ICT-using firms). Production labour-augmenting technological change (modelled as an increase in φ_L) actually leads to convergence. Intuitively, this is because management gets less relevant, and therefore efficiency differences for management matters less.

Figure 6: The effect of other forms of technological change on relative incomes



This indicates that the relative performance of Italy in the future depends very much on the bias of technological change. Even though some people forecase current trends to continue, there is no deep reason why technological change should continue to be always management (or skill)-biased in the future, it has not always been in the past (cf Krugman's review of Gordon's book).

5 Firm level evidence on ICT adoption in Italy and Germany

In this section, we use Eurostat's "Community survey on ICT usage and e-commerce in enterprises" for Italy and Germany to assess our model's predictions. This survey is coordinated by Eurostat, but run by national statistical offices.[24] Access to the micro data is restricted, and must be obtained on a country-by-country base. The Italian data are subject to more stringent privacy restrictions, implying that we do not observe

[23] When the "Italian distortion" is measured instead as a fixed cost of hiring managers, conclusions may change, as convergence forces are strengthened. See the Appendix and Draft 2.5. for further details.

[24] For further details about the survey, see http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Community_survey_on_ICT_u

firms with less than 10 employees and we have very scant firm level information apart from ICT adoption.[25] For both countries, we use data for the year 2014, where the survey contains almost 19,000 firms for Italy and around 7,500 for Germany with more than 10 employees.

5.1 ICT adoption rates

The model predicts two channels through ICT adoption is depressed in Italy. First, conditional on productivity (which we proxy by sales or employment, one-to-one related to productivity in the model), German firms are more likely to adopt ICT, particularly in the middle of the size distribution.[26] This is what we have called the direct effect before, and we refer to it here also as the country effect. Second, there is what we previously called the indirect or size distribution effect: ICT adoption increases in firm size, and Italy has a more left-skewed firm size distribution.

Table 4 reports some first evidence of the diffusion of ICT in firms, as a total and also by employment size classes. The first two columns report the most general indicator of ICT adoption, based on the answer to the question if the firm employs specialists in ICT. We see this as the most direct counterpart of the ICT variable in the model: it indicates that the firm has an ICT department. Overall, 15% of Italian firms hire ICT specialists, against 23% of German firms. This confirms the lower diffusion rate of ICT in Italian firms. In terms of size, the rate of adoption clearly increases with the number of employees in both countries, going from a minimum of 11% in the 10-49 size class in Italy to 81% for the largest size class in Germany. This is also consistent with previous evidence.[27] Note also that, even within size classes, adaption rates are lower in Italy, although the differences are smaller than the overall one. This indicates that both the firm size effect and the country effect are at play in generating the different adoption rates.

Table 4 also examines the existence of alternative hurdles that might explain the lower ICT adoption rates in Italian firms. Our model puts the focus on firms' demand for ICT, but it may also be that the supply of ICT-related human and physical capital is lower in Italy. For example, it might be that the Italian education system does not produce enough workers with ICT competences or that the infrastructure necessary to use ICT, such as high speed Internet connection, is worse in Italy. The data shows, however, that these factors do not seem to matter much. Columns 3 and 4 display the share of firms that reported difficulties in recruiting ICT specialists, among those who were on the market for such workers. Only 30% of firms reported problems

[25]The Italian data are sent directly to the researcher, while the German ones can be accessed remotely, by sending codes whose output is checked for confidentiality issues before been returned to the researcher. As a consequence, the Italian data do not information that might allow to identify the firm, such as the number of employees and sales, but only class dummies.

[26]In the model, adoption is deterministic. Clearly, in reality we observe differences in adoption for observationally equivalent firms. It is easy to generalize the model in terms of a probabilistic adoption choice, for example assuming stochastic adoption costs. This would only make the analysis more complicated without adding anything relevant to our understanding of ICT adoption.

[27]See for example Fabiani et al. (2005) for Italy and Bayo-Moriones and Lera-López (2007) for Spain.

Table 4: ICT diffusion and barriers to adoption in Italy and Germany

	ICT specialists		**Diffic. in hiring**		**Fixed connect.**		**Max speed**	
	[1] ITA	[2] GER	[3] ITA	[4] GER	[5] ITA	[6] GER	[7] ITA	[8] GER
Size class								
10-49	11	15	33	54	95	94	2,40	2,57
50-99	35	39	22	56	97	96	2,55	2,77
100-249	58	57	24	40	97	97	2,63	2,90
250+	74	81	28	53	98	98	3,02	3,50
Total	15	23	30	52	95	95	2,43	2,64

Note: Cells in columns [1]-[6] report the share of firms that have aswered "yes" to the following question: if the firm employs ICT specialists ([1]-[2]); if the firm has encountered difficulties in hiring ICT specialists, only for firms that tried to hire ([3]-[4]); and if the firm has a fixed internet connection ([5]-[6]). Columns [7]-[8] report the maximum download speed. All statistics use survey weights. For clarity, we report unconditional summary statistics. All results are confirmed when we control for sectoral and geographical dummies.

in Italy, against 52% in Germany, indicating that, if anything, there is more scarcity of ICT specialists in Germany than in Italy. In terms of network infrastructures, in both countries 95% of firms have access to a fixed Internet connection (Columns 5 and 6), with the rates also very similar across size classes, indicating that this type of connection is available for the great majority of firms. The maximum speed in download is also similar across countries, although slightly larger in Germany, and increasing in size. Overall, this evidence suggest that demand factors are key to explain the differences in adoption rates between Italian and German firms.

In the model, ICT is a uni-dimensional variable. Of course, in reality there are different ICT technologies that serve different purposes, such as organizational software, software that allows to manage the supply chain, website and social network presence, sales through the Internet etc. In Table 5 we report the adoption rate of four technologies that are likely to have a direct impact on productivity: Enterprise Resource Planning (ERP), Radio-Frequency Identification (RFID) for products, Customer Relationship Management (CRM) and Supply Chain Management (SCM). Broadly speaking, the first two technologies are used to organize production *within* the firm while the other two are used to organize the interaction with entities *external* to the firm, in particular customers and suppliers. As it turns out, there are some differences in adoption patters between the two classes of technologies. For ERP and RFID, total adoption rates are fairly similar between the two countries. In particular, if we compare homogeneous size classes, the adoption rates of Italian firms is very close to that of German firms. So, while the firm size effect is at play, little evidence of the country size effect emerges. In the case of CRM and SCM, instead, both effects are present: adoption rates are lower in Italy, both in total but also comparing firms in the same size classes. Seen through the lenses of

Table 5: Key indicators of ICT adoption in Italy and Germany

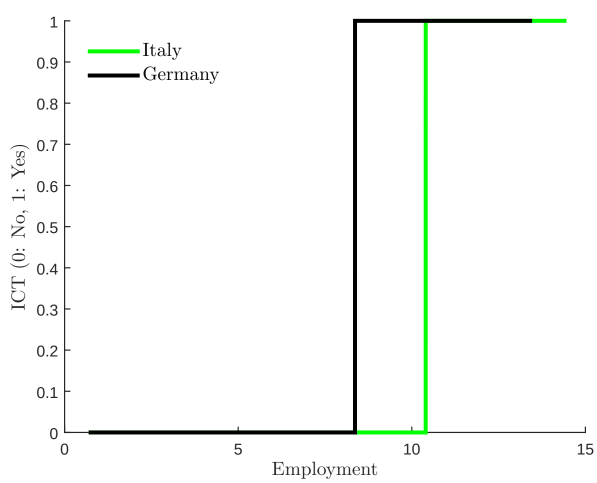
	ERP		RFID		CRM		SCM	
	[1] ITA	[2] GER	[3] ITA	[4] GER	[5] ITA	[6] GER	[7] ITA	[8] GER
Size class								
10-49	34	33	3	3	17	25	15	20
50-99	58	60	8	4	27	36	21	33
100-249	70	68	11	8	31	40	23	38
250+	79	85	12	12	36	48	36	57
Total	38	41	4	4	19	28	16	24

Note: Each cell reports the share of firms that have answered "yes" to the following questions: if the firm uses enterprise resource planning software (ERP, [1]-[2]); if the firm uses Radio-Frequency Identification technology to monitor the production process (RFID, [3]-[4]); if the firm uses Customer Relationship Management software to organize and process information about customers (CRM, [5]-[6]); if the firm uses Supply Chain Management software to communicate and coordinate with customers and suppliers (SCM, [7]-[8]). All statistics use survey weights.

our model, this results can be explained with different technology-specific degrees of delegation inefficiency in Italy. In particular, the inefficiency with respect to Germany would be small for technologies that mostly entail delegation within the firm, and higher for technologies that allow the firm to interact with the external environment.

Finally, there is one last, more specific prediction of the model which we can test in the data: the difference in ICT adoption rates should be largest for firms of intermediate size, as illustrated in Figure 7.

Figure 7: Employment and ICT adoption in the model

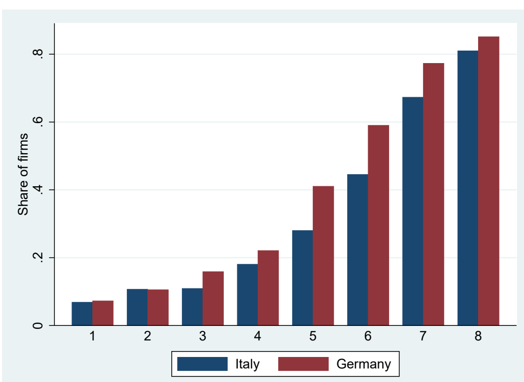


Note: Employment includes workers and managers, but not labour hired to cover fixed costs.

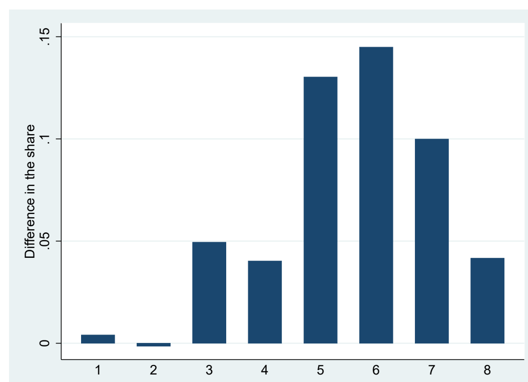
In fact, in both countries all small firms do not adopt while all large firms adopt ICT. It is at intermediate size levels that German firms might adopt while Italian firms might not. Unfortunately, the employment categories of the public version of the dataset are very coarse and, for Italy, we have no information at the level of the firm on employees. However, the Italian data report a more disaggregate size class in terms of sales, that allows to separate firms into 8 sales size classes. Given that we have sales information for German firms, we can group firms using the same same size classes and compare their adoption rates. We consider the most comprehensive indicator of ICT adoption, that is, if the firm employs ICT specialists. Figure 8 plots the histograms of the share of firms employing ICT specialists by sales class. Panel a) shows the absolute values. Clearly, adoption rates are increasing in size, even when considering this different size indicator (sales rather than employees) and with a finer division (eight classes versus four). Adoption rates are slightly higher in Germany, and the difference seems to peak at the center of the distribution. To see this more clearly, Panel b) plots the difference in adaption between German and Italian firms by size classes. The pattern is consistent with our theoretical prediction: adoption rates are very similar for small firms, they move apart for the middle part of the distribution, where they reach a maximum of 15% for the sixth size class, and decline for the two largest size classes.

Figure 8: Firms employing ICT specialists, by sales classes

(a) Absolute values



(b) Differences Germany/Italy

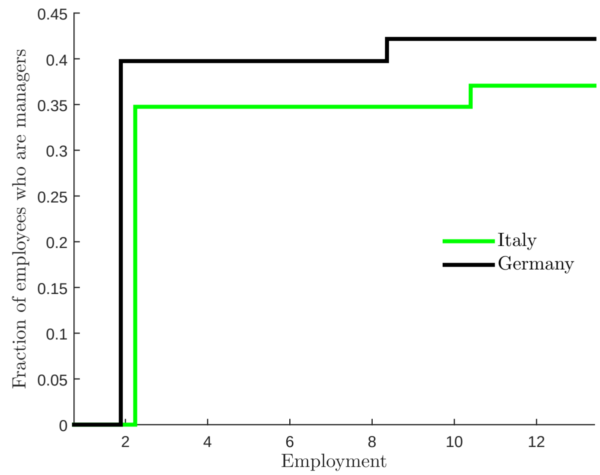


Note: The x-axis represents the sales size classes, with 1=(50,0000-99,9999), 2=(1,000,000-1,999,999), 3=(2,000,000-3,999,999), 4=(4,000,000-9,999,999), 5=(10,000,000-19,999,999), 6=(20,000,000-49,999,999),7=(50,000,000-199,999,999), 8=(200,000,000+). The y-axis reports the share of firms adopting, with the absolute values in Panel a) and their difference in Panel b).

5.2 Managers

The key assumption of the our model is that delegation efficiency is lower in Italy. This implies that Italian firms are less likely to hire managers, and even if they do, hire less than their German counterparts. Figure 9 illustrates this result in our model, by plotting, for both countries, firm employment against the share workers who are managers.

Figure 9: Employment and manager share in the model



Note: Employment includes workers and managers, but not labour hired to cover fixed costs. The discontinuity in the graph is due to ICT adoption, which creates a discontinuity in the employment distribution.

Unfortunately, the ICT survey collects no information on the structure of the workforce, so that we cannot compare firms in terms of the number or the productivity of managers. As a (admittedly imperfect) proxy, we use indicators of the training policies of firms. Firms are asked if, over the last year, they held training courses on ICT, both for workers with ICT-specific skills and for workers without ICT-specific skills. Although firms might train all types of workers, it is likely that training is directed mostly towards workers with positions higher in the hierarchy. If this is the case, training depends on the size of the managerial component of the workforce, as well as on the adoption of ICT. We therefore interpret this as measure of the composite productivity term $\mathcal{X}$, that depends on the product of the size of the managerial workforce and ICT adoption. Table 6 displays the share of firms offering training to their employees. In this case, the differences between Italy and Germany are very marked: only 5% of Italian firms offer training classes to ICT specialist, against 16% of German ones. The difference in even more marked for non ICT specialists (8% against 34%). Moreover, as suggested by Figure 9, these differences occur within every size class.

Table 6: Share of firms offering ICT training classes

	To ICT specialists		**To non ICT specialists**	
	[1]	**[2]**	**[3]**	**[4]**
Size class	ITA	GER	ITA	GER
10-49	3	10	6	28
50-99	11	24	16	44
100-249	20	41	27	55
250+	39	69	40	77
Total	5	16	8	34

Note: each cell reports the share of firms that have aswered "yes" to the relative question: if the firm held trainig classes for ICT specialists ([1]-[2]); if the firm held trainig classes for non ICT-Specialists ([3]-[4]) All statistics use survey weights.

5.3 The productivity effect of ICT and managers

In our model, larger firms are more productive, both because they have larger exogenous productivity draws and because they are more likely to hire managers and use ICT. At the same time, controlling for ICT adoption, the size effect should decrease or even disappear. In fact, if ICT adoption were a continuous variable, as the choice of the number of managers, there would be a one to one relationship between the exogenous productivity A, total productivity $(A(i)\mathcal{X}(i))^{\frac{1}{\varepsilon-1}}$ and firm size. A regression of productivity on size classes and measures of ICT adoption should show that productivity is explained by ICT adoption, reducing the importance of size. Moreover, given the lower delegation efficiency of Italian firms, we should find that productivity is more sensitive to the interaction between managers and ICT in Germany than in Italy. Unfortunately, at the moment we have no access to data that would allow us to test these predictions. First, in both countries we have no measure of managerial inputs. Second, we have a (rough) measure of labour productivity only for Germany, where we have data on sales and on the number of employees, so that we can compute sales per worker. However, we can still check if, for German firms, the relationship between size and productivity changes as we control for ICT adoption.

We do so in Table 7. In column [1] we only control for size dummies, in addition to industry and regional dummies, included in all regressions, so that all the coefficients we estimate are net of regional and sectoral effects. As expected, productivity monotonically increases with size: firms with 50-99 employees produce on average approximately 15% more sales per worker than firms with 10-49 employees, those with 100-249 employees 25% more and those with 250 or more employees 30% more. In Column [2] we include a dummy for firms hiring ICT specialists. The dummy is highly significant and the effect is substantial: firms with

ICT specialists have a productivity 2/3 higher than firms without them. Interestingly, once we include this variable the size dummies loose significance. Of course, this relationship should not be interpreted as causal. However, it does indicate that even a binary indicator of ICT adoption is a sufficient statistic to capture productivity and that, conditional on ICT usage, size does not matter anymore. In Column [3] we include the training dummies relative to ICT specialists (results do not change if we use training for non ICT specialists). The pattern is very similar to that in column [2]. Results are also confirmed when we control for ERP adoption (Column [4]). In the next two columns we include the dummies for adoption of the technologies that we defined as allowing to manage relationships "external" to the firm, that is, Customer Relationship Management /CRM and Supply Chain Management. We argued that these technologies are less about the internal organization of the firm and more about how the firm relates to customers/suppliers. As such, their effects on efficiency might be not as strong as for the ERP, that instead allows to organize and manage production processes within the firm. We find that firms that have adopted these technologies are indeed more productive, but the effect of size in this case survives, although smaller than in the baseline regression of Column [1]. Of course, as Table 6 shows, the diffusion rate of these technologies is lower than that of ERP, which might also explain why the size effect survives their inclusion. This is even more apparent when we consider Radio Frequency Identification, that only 4% of firms have adopted (Column [7]). Finally, in Column [8] we perform a horse race and include all the indicators at the same time. Not surprisingly, the effect of each one of regressors is reduced, as different measures of ICT adoption tend to be correlated within firms. Even so, the dummies for the presence of ICT specialists, training, ERP and SCM are still highly significant. With all these controls, the size dummies turn negative, possibly suggesting that, controlling for ICT adoption, the production technology display decreasing returns to scale.

Table 7: Productivity, size and ICT adoption

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Size dummies								
50-99 emp	0.142***	0.025	0.021	-0.019	0.074**	0.091***	0.095***	-0.042
	(0.029)	(0.029)	(0.030)	(0.030)	(0.030)	(0.029)	(0.030)	(0.032)
100-249 emp	0.229***	0.014	0.015	0.006	0.134***	0.153***	0.171***	-0.076**
	(0.033)	(0.035)	(0.035)	(0.035)	(0.034)	(0.032)	(0.034)	(0.037)
250+ emp	0.272***	-0.062*	-0.085**	-0.030	0.154***	0.123***	0.198***	-0.218***
	(0.032)	(0.037)	(0.039)	(0.036)	(0.033)	(0.033)	(0.033)	(0.044)
ICT specialist		0.513***						0.082**
		(0.029)						(0.037)
Training			0.486***					0.147***
			(0.031)					(0.037)
ERP				0.499***				0.269***
				(0.029)				(0.031)
CRM					0.259***			-0.011
					(0.025)			(0.031)
SCM						0.369***		0.157***
						(0.025)		(0.027)
RFDI							0.098*	-0.024
							(0.052)	(0.052)
Cons.	11.277***	11.291***	11.381***	11.240***	11.293***	11.248***	11.377***	10.916***
	(0.085)	(0.084)	(0.089)	(0.085)	(0.090)	(0.085)	(0.090)	(0.114)
R-sq	0.1057	0.1469	0.1420	0.1487	0.1190	0.1317	0.1071	0.2578
No. Obs	7583	7493	6900	7040	6966	7534	6889	6303

Note: The dependent variable is the log of sales per worker. 50-99 emp is a dummy for firms with between 50 and 99 employees, and similarly for the other size dummies, with the excluded category being firm with 10-49 employees. ICT specialists is a dummy equal to one if the firm employes ICT specialist. training ERP CRM SCM RFDI .... all regressions include 30 industry and 16 regional dummies. Robust standard errors in parenthesis. *** indicate significance at 1%, ** at 5%, * at 10%.

With more data on both countries, regressions of this type may help us to pin down the values of the parameters ξ and φ, which would be key for a quantitative analysis.

5.4 Productivity growth and firm size

Finally, our model also has predictions for how the ICT revolution should change the joint distribution of productivity and size.

When defining productivity as TFP, and employment as the sum of production workers and managers, the model holds (as any Melitz model)

$$\text{TFP} = \left(\frac{\text{Employment}}{(\varepsilon - 1)\,\frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}.$$

Therefore, the productivity ratio of a firm with 100 employees to a firm with 10 employees only depends on employment and on ε, and is not modified by the ICT revolution. Note, however, that this is physical productivity. Revenue TFP will actually be equalized across all firms (for instance, sales per employee are the same at all firms).

When one defines instead productivity as output per production worker, and puts this in relation with the enployment of production workers, one gets

$$\frac{\text{Output}}{\text{Production workers}} = \left(\frac{\text{Production workers}}{(\varepsilon - 1)\,\frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}} \mathbb{1}_M \widetilde{\xi}^{\sigma + \frac{\varepsilon - \sigma}{\varepsilon - 1}}.$$

Therefore, under the sufficient condition $\varepsilon > \sigma$,[28] after the ICT revolution, the productivity ratio between a firm with 100 production workers (that adopts ICT) and a firm with 10 production workers (that does not) must increase.

The model predicts, like any Melitz-style model, that larger firms are more productive, in every country. Table 8 shows that this is the case, both in Germany and in Italy.

Table 8: Value added per worker by size class

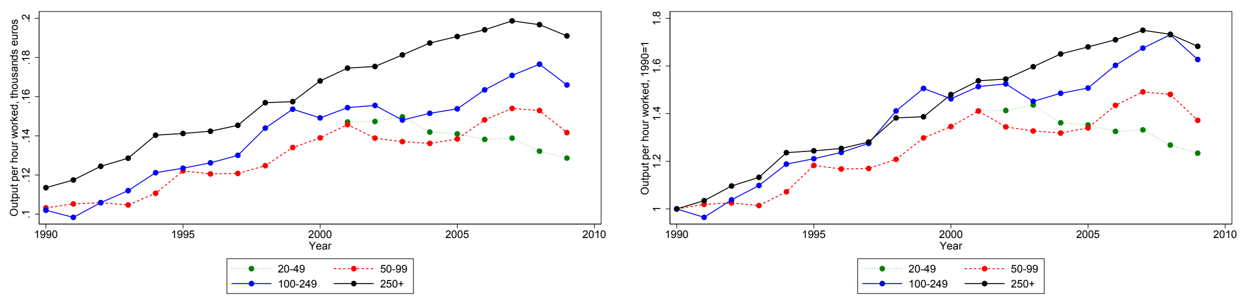
	Germany	Italy	Spain	Total
Size class				
10-49	40,7	46,7	42,0	43,1
50-249	51,9	51,1	60,0	54,4
250+	82,4	64,4	69,1	72,1
Total	58,4	53,9	56,8	56,4

[28]Which is a necessary and sufficient condition for the employment of production workers to be monotonically increasing in productivity A.

Figure 10: Productivity growth by size class (number of employees)

(a) Productivity levels (output per hour, thousands euros)

(b) Productivity, Index numbers, 1990=1



How did productivity growth evolve in different size classes? We can assess this question for Italy, where we have access to a firm level dataset representative of the population of manufacturing firms. Up to 2000, the dataset only sampled firms with at least 50 employees. Starting in 2001, the survey covers firms with at least 20 employees. We divide firms in 4 size classes according to the number of employees: 20-49, 50-99, 100-249, 250+. Within each class, we compute average productivity as output per worker, dropping the first and last percentile of the productivity distribution in each class-year (results are similar when keeping all firms). Figure 10, Panel a) reports output per hours worked in thousands euros, and Panel be the index number. For firms in the smaller size class we normalize productivity in 2001 to the level of the index for the 50-99 size class.

First, we confirm that average productivity grows with firm size: in 2009, output per hour worked was around 150 euros in larger firms and less than 100 in the smallest size class. More interestingly, it appears that the gap has been widening over time. This is apparent from panel b), where we plot the index for labor productivity, fixed to 1 in 1990.[29] Productivity evolves fairly similarly across size classes up to 1995, when it starts to diverge: firms in the 50-99 size class record a lower productivity growth. The divergence becomes more apparent from 2001, when productivity growth turns negative in the two smaller size classes, particularly in the 20-49 one. This divergence could be due to the fact that only the large firms adopted ICT, but we need more work to tie it exactly to the predictions of the model.

[29] For the 20-49 size class, we fix the value of the index in 2001 to that of the 50-99 size class: in fact, in panel a) the productivity level of these two categories is basically the same in 2001.

References

Akcigit, Ufuk, Harun Alp, and Michael Peters, "Lack of Selection and Limits to Delegation: Firm Dynamics in Developing Countries," NBER Working Papers 21905, National Bureau of Economic Research, Inc January 2016.

Bayo-Moriones, Alberto and Fernando Lera-López, "A firm-level analysis of determinants of ICT adoption in Spain," *Technovation*, 2007, *27* (6), 352–366.

Bloom, Nicholas, Raffaella Sadun, and John Van Reenen, "Americans Do IT Better: US Multinationals and the Productivity Miracle," *American Economic Review*, February 2012, *102* (1), 167–201.

_ , Renata Lemos, Raffaella Sadun, Daniela Scur, and John van Reenen, "Jeea-Fbbva Lecture 2013: The New Empirical Economics Of Management," *Journal of the European Economic Association*, 08 2014, *12* (4), 835–876.

Brynjolfsson, Erik and Andrew McAfee, *The Second Machine Age*, W.W. Norton, 2014.

_ and Lorin M. Hitt, "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," *Journal of Economic Perspectives*, Fall 2000, *14* (4), 23–48.

Bugamelli, Matteo, Luigi Cannari, Francesca Lotti, and Silvia Magri, "The innovation gap of Italy's production system: roots and possible solutions," 2012. Bank of Italy Occasional Paper 121.

Bustos, Paula, "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, February 2011, *101* (1), 304–40.

Calligaris, Sara, "Misallocation and Total Factor Productivity in Italy: Evidence from Firm-Level Data," CEIS Research Paper 357, Tor Vergata University, CEIS October 2015.

_ , Massimo Del Gatto, Fadi Hassan, Gianmarco I.P. Ottaviano, and Fabiano Schivardi, "Italyâs Productivity Conundrum. A Study on Resource Misallocation in Italy," European Economy - Discussion Papers 2015 - 030, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission May 2016.

Chaney, Thomas, "Distorted Gravity: The Intensive and Extensive Margins of International Trade," *American Economic Review*, September 2008, *98* (4), 1707–21.

Daveri, Francesco and Maria Laura Parisi, "Experience, Innovation and Productivity - Empirical Evidence from Italy's Slowdown," Technical Report 2010.

Fabiani, Silvia, Fabiano Schivardi, and Sandro Trento, "ICT adoption in Italian manufacturing: firm-level evidence," *Industrial and Corporate Change*, 2005, *14* (2), 225–249.

Fernald, John, "Productivity and Potential Output Before, During, and After the Great Recession," in "NBER Macroeconomics Annual 2014, Volume 29" October 2014.

Garicano, Luis, "Can slow IT adoption explain productivity slowdown? Firm size and organizational change," Presentation to CompNet-ECB Workshop, Madrid 2015.

_ **and Paul Heaton**, "Information Technology, Organization, and Productivity in the Public Sector: Evidence from Police Departments," *Journal of Labor Economics*, 01 2010, *28* (1), 167–201.

_ **, Claire Lelarge, and John Van Reenen**, "Firm Size Distortions and the Productivity Distribution: Evidence from France," NBER Working Papers 18841, National Bureau of Economic Research, Inc February 2013.

Gordon, Robert J., *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War*, Princeton University Press, 2016.

Gros, Daniel, "What is holding Italy back?," VoxEU.org 2011.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, November 2003, *71* (6), 1695–1725.

_ **and Stephen J. Redding**, "Heterogeneous Firms and Trade," in Elhanan Helpman Gita Gopinath and Kenneth Rogoff, eds., *Handbook of International Economics*, Vol. 4 of *Handbook of International Economics*, Elsevier, 2014, pp. 1 – 54.

O'Mahony, Mary and Marcel P. Timmer, "Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database," *Economic Journal*, June 2009, *119* (538), F374–F403.

Pagano, Patrizio and Fabiano Schivardi, "Firm Size Distribution and Growth*," *The Scandinavian Journal of Economics*, 2003, *105* (2), 255–274.

Pellegrino, Bruno and Luigi Zingales, "Diagnosing the Italian Disease," Working Paper, 2014.

Schivardi, Fabiano and Roberto Torrini, "Identifying the effects of firing restrictions through size-contingent differences in regulation," *Labour Economics*, June 2008, *15* (3), 482–511.

Solow, Robert M., "We'd Better Watch Out," *The New York Times Book Review*, July 1987.

A Theoretical Appendix

A.1 Proofs

A.1.1 Proof of Proposition 1 and additional cases

The next proposition lists the three additional configurations which can occur.

Proposition 2. *If* $f \leq \frac{f_M + f_{ICT}}{\widetilde{\xi}_{ICT}^{\varepsilon-1} - 1}$ *and* $f_{ICT} \leq \frac{\widetilde{\xi}_{ICT}^{\varepsilon-1} - \widetilde{\xi}_{NoICT}^{\varepsilon-1}}{\widetilde{\xi}_{NoICT}^{\varepsilon-1} - 1} f_M$*, then cut-offs hold* $A_E^* < A_M^* = A_{ICT}^*$*, and are given by* $A_E^* = \frac{1}{\varphi_N \varphi_L} \left(\frac{f}{\frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}$*, and* $A_M^* = A_{ICT}^* = \frac{1}{\varphi_N \varphi_L} \left(\frac{f_M + f_{ICT}}{\left(\widetilde{\xi}_{ICT}^{\varepsilon-1} - 1\right) \frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}$.

Case 3. *If* $\left(\widetilde{\xi}_{NoICT}^{\varepsilon-1} - 1 \right) f > f_M$ *and* $f_{ICT} > \frac{\widetilde{\xi}_{ICT}^{\varepsilon-1} - \widetilde{\xi}_{NoICT}^{\varepsilon-1}}{\widetilde{\xi}_{NoICT}^{\varepsilon-1}} (f + f_M)$*, then cut-offs hold* $A_E^* = A_M^* < A_{ICT}^*$*, and are given by* $A_E^* = A_M^* = \frac{1}{\varphi_N \varphi_L \widetilde{\xi}_{NoICT}} \left(\frac{f + f_M}{\frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}$*, and* $A_{ICT}^* = \frac{1}{\varphi_N \varphi_L} \left(\frac{f_{ICT}}{\left(\widetilde{\xi}_{ICT}^{\varepsilon-1} - \widetilde{\xi}_{NoICT}^{\varepsilon-1} \right) \frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}$.

Case 4. *If* $\left(\widetilde{\xi}_{NoICT}^{\varepsilon-1} - 1 \right) f > f_M$ *and* $f_{ICT} \leq \frac{\widetilde{\xi}_{ICT}^{\varepsilon-1} - \widetilde{\xi}_{NoICT}^{\varepsilon-1}}{\widetilde{\xi}_{NoICT}^{\varepsilon-1}} (f + f_M)$*, or else if* $\left(\widetilde{\xi}_{NoICT}^{\varepsilon-1} - 1 \right) f > f_M$ *and* $f_M + f_{ICT} < \left(\widetilde{\xi}_{NoICT}^{\varepsilon-1} - 1 \right) f$*, then cut-offs hold* $A_E^* = A_M^* = A_{ICT}^*$*, and are given by* $A_E^* = A_M^* = A_{ICT}^* = \frac{1}{\varphi_N \varphi_L \widetilde{\xi}_{ICT}} \left(\frac{f + f_M + f_{ICT}}{\frac{B}{w}} \right)^{\frac{1}{\varepsilon - 1}}$.

New proof to come (see handwritten notes).

A.1.2 Uniqueness of the equilibrium

To show that Equation (7) admits a unique solution for $\frac{B}{w}$ irrespective of parameter values, we can rewrite that equation as $f_E = \Phi\left(\frac{B}{w}\right)$. Then, note that $\lim_{\frac{B}{w} \to 0} \Phi\left(\frac{B}{w}\right) = 0$ and $\lim_{\frac{B}{w} \to +\infty} \Phi\left(\frac{B}{w}\right) = +\infty$. Furthermore, after some algebra, it comes that

$$\Phi'\left(\frac{B}{w}\right) = \eta^{\alpha} \int_{A_E^*}^{A_M^*} A g(A)\, dA + \left(\alpha \xi \frac{B}{w}\right)^{\frac{\alpha}{1-\alpha}} \left[\int_{A_M^*}^{A_{ICT}^*} A^{\frac{1}{1-\alpha}} g(A)\, dA + \varphi^{\frac{\alpha}{1-\alpha}} \int_{A_{ICT}^*}^{+\infty} A^{\frac{1}{1-\alpha}} g(A)\, dA \right] > 0.$$

This proves that Equation (7) has indeed a well-defined solution for $\frac{B}{w}$ in the interval $(0, +\infty)$.[30]

A.2 A model with a fixed cost of management

In this section, we consider an extension of the model presented in the main text, in which firms which use managers need to pay (on top of the wage of these managers) a fixed cost of f_M units of labour, capturing the costs of adjusting to a decentralized organizational structure. This model gives some predictions which are different from the ones in the main text.

[30] Note that none of the statements in this paragraph depends on whether the model is in Case 1, 2, 3 or 4 of Proposition 1: they are equally valid in all four cases.

1. With a variable distortion ξ, productivity differences among the largest (most productive firms) in Italy and Germany increase with the ICT revolution. With a fixed distortion f_M, they remain unchanged.

2. With a fixed distortion f_M, conditional on having managers and controlling for productivity, German firms have less managers than Italian ones (which is again due to $\frac{B}{w}$ being higher in Italy). With a variable distortion ξ, German firms may have more managers (depending on the balance of higher ξ and lower $\frac{B}{w}$).

See Draft 2.5 for a solution to the model.