The ICT Revolution and Italy's Two Lost Decades*

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Abstract

Since the middle of the 1990s, Italy's GDP and productivity growth rates have virtually fallen to zero, and Italy's economy is falling ever further behind Northern Europe and the United States. We argue that an important reason behind the Italian slowdown is the failure of Italian firms to take up the ICT revolution. This, in turn, may be due to long-standing distortions in their internal organization, characterized by small size, centralized management, and low numbers of non-family managers. To explore this hypothesis, we write a heterogeneous-firm model with ICT and management, assuming that ICT enters firms' production functions as management-augmenting technological change. In the model, inefficient management causes low ICT adoption, both directly (as management and ICT are complements) and indirectly (as inefficient management in large firms allows more unproductive non-ICT adopting firms to survive). Increases in ICT productivity widen income differences between economies with efficient and inefficient management, both because the former use more ICT and because ICT increases the importance of management for aggregate production. Using microdata from different surveys on ICT and managers in firms in Italy and other European countries, we document empirical regularities that are in line with the model's predictions. Eventually, we want to use this data to assess how much of Italy's divergence can be explained by the ICT revolution.

Keywords: Italy, Productivity slowdown, ICT adoption, Management.

JEL Codes: L23, O33

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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 in the internal organization of Italian firms, characterized by small size, centralized management, and low numbers of non-family managers. 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).

[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 inefficient management on ICT adoption, we write a heterogeneous-firm model with technology adoption and management, building on a closed-economy version of Melitz (2003). Firms operate under monopolistic competition, and produce differentiated goods with an exogenously drawn productivity, using production workers and managers. Managers lower firms' marginal costs, but hiring them has a fixed cost. Therefore, only firms with high productivity draws employ managers in equilibrium, while the others use only production workers. Firms can also adopt ICT, by paying another fixed cost. Importantly, we assume that ICT increases the productivity of a firm's managers (that is, it is management-augmenting technological change). Thus, only firms with managers adopt ICT, and among them, there is again a selection based on productivity, due to the fixed costs of ICT. Finally, there is also a general fixed cost of production, so that the firms with the very lowest productivity leave the market and do not produce.

We use the model to compare two economies which are equal except for one parameter governing manager productivity. As shown by Akcigit et al. (2016), differences in manager productivity can capture, in a reduced-form way, differences in "delegation efficiency", that is, distortions affecting the process of managerial delegation, such as an inefficient judiciary system, or lack of trust towards managers.[6] In the economy with lower delegation efficiency (which we call Italy), firms are less likely to hire managers, and conditional on doing so, they hire less of them. Therefore, the firms with the highest productivity draws do not expand as much, allowing more small, low-productivity firms to survive in equilibrium. Low delegation efficiency also causes low ICT adoption. First, for the same productivity draw, a firm in a country with low delegation efficiency has less incentives to adopt ICT, as the latter is management-augmenting. Second, that country also has a larger tail of unproductive firms, which do not adopt ICT because of its fixed cost.

Finally, we show that an increase in the productivity of ICT always increases aggregate productivity and income differences between Italy and an economy with more efficient managers. This is in part due to the direct effect of lower ICT adoption in Italy, but there is also an indirect effect: as ICT is management-augmenting technological change, it increases the importance of managers (less efficient in Italy) for aggregate output, and decreases the importance of production workers (equally efficient in Italy). In sum, the ICT revolution causes divergence because it accentuates a long-standing weakness of the Italian economy, inefficient management.

To test the model's predictions and to quantify the importance of its mechanisms, we turn to firm-level data, using the Eurostat "*Community survey on ICT usage and e-commerce in enterprises*", as well as the "*EU-EFIGE/Bruegel-UniCredit dataset*", in short EFIGE, assembled under the coordination of the Bruegel research institute. Both datasets contain firm-level information about ICT usage, management and a number of other variables for Italy and several other European countries. We mainly compare Italy to Germany, the largest economy in the Eurozone (a conservative choice, as ICT adoption in Germany has not been stellar).

[6] 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.

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.

First, using the Eurostat survey on ICT usage, 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) 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.

Using the EFIGE dataset, which also has detailed information on firms' management structure, we document that, in line with the model, Italian firms both are less likely to hire external managers and hire less of them, across all size classes. We then show that manager and ICT usage have a positive impact on measured productivity, and that there is empirical support for the complementarity between these two elements emphazised by the model. Eventually, we want to push these exercise more fully towards a structural estimation of the model's key parameters, in order to be able to assess how much of the divergence between Italy and other European countries during the last twenty years can be attributed 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.[7]

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))

[7] 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.

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.

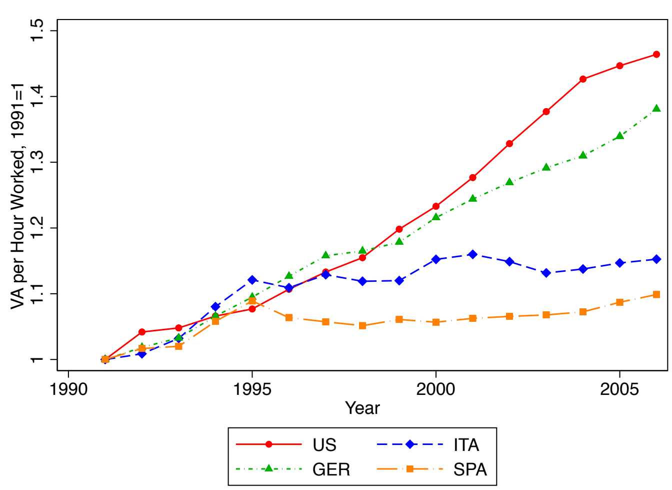
The remainder of the paper is structured as follows. Section 2 presents some stylized facts on the Italian productivity slowdown, the ICT revolution, and the management and size structure of Italian firms. Section 3 introduces our model, and Section 4 studies its predictions for the impact of the ICT 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 and the ICT revolution

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.

Figure 1: Labour productivity growth in selected countries, 1991-2007



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

The figure, which uses data from the EU KLEMS database,[8] 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 for TFP. While the EU KLEMS database has the disadvantage of being available only up to 2007,[9] Table 1 shows that these trends have not been inverted since then.

Table 1: GDP and productivity growth in selected countries, 1995-2015

Country	Growth rate, 1995-2015		
	Real GDP	Real GDP/hour worked	TFP
Italy	10%	6%	-4%
Spain	50%	16%	-3%
Eurozone	34%	24%	n.a.
Germany	30%	28%	17%
USA	61%	40%	22%

Source: OECD.Stat. The Eurozone refers to the 19 member states in 2016. TFP growth for Spain refers to the period 1995-2013.

Importantly, the Italian slowdown is not due 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.

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.[10]

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 five 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)).[11] The increase has been lower but still substantial in Germany, while it was much

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

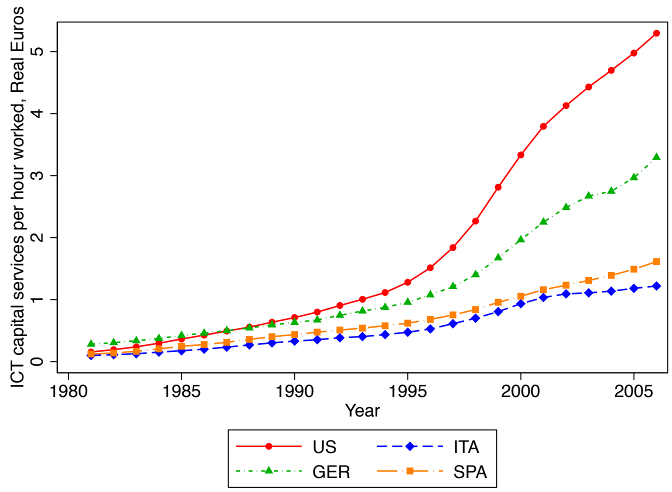
[9]We use data from 1991 (the first year of the German Unification) onwards.

[10]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.

[11]The literature typically explains the Solow paradox, and the delay of ICT showing up in productivity statistics, with the

more modest in Italy: in 2007, ICT capital services per hour worked in Italy were around one euro (against three for Germany).

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



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 this fact. The next section discusses some structural features of the Italian economy which may have caused low ICT adoption.

2.2 Delegation efficiency and firm size

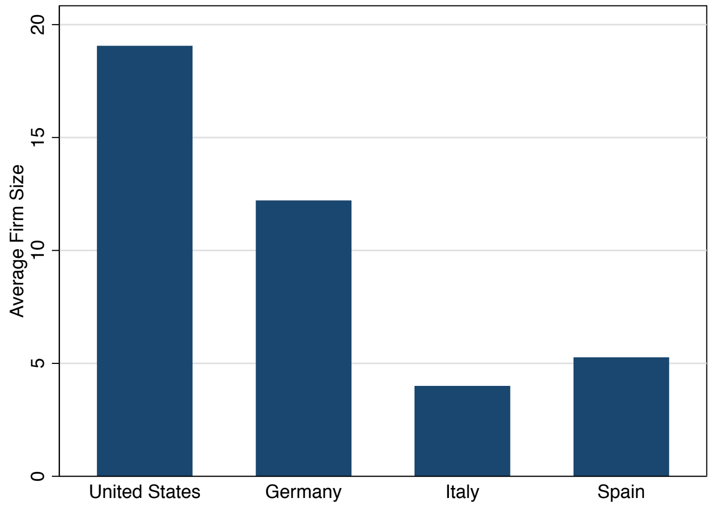
Italy differs from Northern Europe and the United States in many aspects that might account for lower ICT penetration. For instance, the educational attainment of the working population is lower, and infrastructure is less developed. In this paper, however, we focus on one specific factor which can explain low ICT demand from Italian firms, namely their internal organization. Two features of Italian firms are especially striking in international comparison.

First, the family of the owner plays a dominant role in a large number of Italian firms, as is illustrated by Table 2, taken from Bugamelli et al. (2012), who use the EFIGE database (representative of firms with more than 10 employees, see Section 5 for further details). The table shows that while family ownership of firms is very common in most European countries[12], Italy stands out for the share of family firms that are fully controlled by the owning family (i.e., that do not have any managers from outside that family). This is the case for two thirds of all Italian firms, whereas in Northern Europe, it is the case for less than 30%. This

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.

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

Figure 3: Average firm size



striking fact suggests inefficiencies in the managerial delegation process in Italy. Indeed, the prevalence of family managers is generally seen as a way to overcome frictions in the delegation of decisions to external managers. However, this comes at an efficiency cost, as family firms without external managers tend to perform worse in measures of good management (Bloom et al. (2014)).

Table 2: Share of firms with family ownership and control (in percentage points)

	Family owned firms	**Within family 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)).

Second, Italian firms are small. For instance, Eurostat's Structural Business Statistics indicate that the average US firm has around 19 employees, the average German firm has around 12 employees, but the average Italian firm has less than 5 (see Figure 3). 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.

These features may explain why Italy has adopted so little ICT, given that ICT adoption has been shown to be positively correlated with firm size and with the efficiency of managerial practices (see, for instance, Bloom et al. (2012)). In the next section, we present a simple heterogeneous-firm model consistent with this idea. The model shows that cross-country differences in manager productivity or "delegation efficiency" can rationalize a large number of the stylized facts discussed in this section and help us to understand the mechanisms at work.

3 The 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, but for hiring managers, there is an additional fixed cost 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.[13]

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 (Brynjolfs-

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

son 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 managers' productivity. This is the model's most important parameter. Indeed, in 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 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.[14] Thus, while differences in ξ between Italy and Germany could be simply due to differences in the human capital of managers, they could also be due to differences in the contractual environment (for instance, in the efficiency of the judicial system), or cultural factors such as trust or social norms.

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

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 $c(i) = p(i)^{-\varepsilon} C$. 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

[14] Their microfoundation is a principal-agent game where managers can shirk and courts may not inforce the contractual rights of firm owners.

hire managers, the marginal cost of production is $\frac{w}{A\varphi_N\varphi_L}$, and therefore, profits are[15]

$$\pi_{\text{NoMan}}(A) = (A\varphi_N\varphi_L)^{\varepsilon-1}B - fw, \tag{3}$$

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

$$\pi_{\text{Man}}(A) = \left(A\varphi_N\varphi_L\widetilde{\xi}\right)^{\varepsilon-1}B - (f + f_M + \mathbb{1}_{ICT}f_{ICT})\,w. \tag{4}$$

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 3 below. As ICT is a management-augmenting technology, firms never adopt it without hiring managers, so we abstract from this option.

Table 3: 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 3 shows that firms' decisions between their different options only depend on one firm-specific variable,

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

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, 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*

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

these cut-offs hold $A^*_E < A^*_M < A^*_{ICT}$, and are given by

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

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

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

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,

$$\begin{aligned} wf_E = & \int_{A_E^*}^{A_M^*} \left((A\varphi_N\varphi_L)^{\varepsilon-1} B - fw \right) dG(A) \; + \int_{A_M^*}^{A_{ICT}^*} \left(\left(A\varphi_N\varphi_L\widetilde{\xi}_{\text{NoICT}} \right)^{\varepsilon-1} B - (f+f_M)\, w \right) dG(A) \\ & + \int_{A_{ICT}^*}^{+\infty} \left(\left(A\varphi_N\varphi_L\widetilde{\xi}_{\text{ICT}} \right)^{\varepsilon-1} B - (f+f_M+f_{ICT})\, w \right) dG(A) \end{aligned} \tag{5}$$

Dividing both sides by the wage and rearranging gives

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

Substituting in the definitions of the cut-offs A_E^*, A_M^* and A_{ICT}^* given in Proposition 1, Equation (6) 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

$$w = \left(\frac{L}{\varepsilon - 1} \left(\frac{\varepsilon}{\varepsilon - 1} \right)^{-\varepsilon} \frac{1}{\frac{B}{w}} \right)^{\frac{1}{\varepsilon-1}}. \tag{7}$$

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

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

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 4 lists labour demand for different uses.

Table 4: Labour demands

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

Note: Further details are provided in the Appendix.

Imposing labour market clearing, and using the free-entry condition, Equation (6) gives

$$M_E=\frac{L}{\varepsilon\left(f_E+f\left(1-G\left(A_E^*\right)\right)+f_M\left(1-G\left(A_M^*\right)\right)+f_{ICT}\left(1-G\left(A_{ICT}^*\right)\right)\right)}. \tag{8}$$

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[16]

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

As the ratios A_E^*/A_M^* and A_E^*/A_{ICT}^* are pinned down by parameters, Equation (9) 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

$$M_E=\frac{(\varepsilon-1) L}{\varepsilon k f_E}. \tag{10}$$

[16] 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.

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

4 Delegation efficiency and the ICT Revolution

We are now ready to analyse the main implications of the model. To do so, we consider two identical closed economies, called Italy and Germany, which are only differentiated by the fact that Italian delegation efficiency is lower: $\xi_I < \xi_D$.[17]

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, $\varphi_{ICT} = 0$. Prior to the ICT revolution, in Italy, and compared to Germany,

- Real income per capita is lower.
- The percentage of firms hiring managers is lower, and firms need a higher productivity draw to start hiring managers (that is, $A^*_{M,I} > A^*_{M,D}$). Furthermore, conditional on hiring managers, firms choose a lower ratio of managers to production workers. As a result, a smaller fraction of the overall workforce works as managers.
- Selection on productivity is less harsh: a larger percentage of firms paying the entry cost start to produce (that is, $A^*_{E,I} < A^*_{E,D}$).
- There is a larger mass of firms M.

As in any Melitz-type model, 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 its larger number of firms offers Italian consumers a greater variety of differentiated goods. 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

[17] 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.

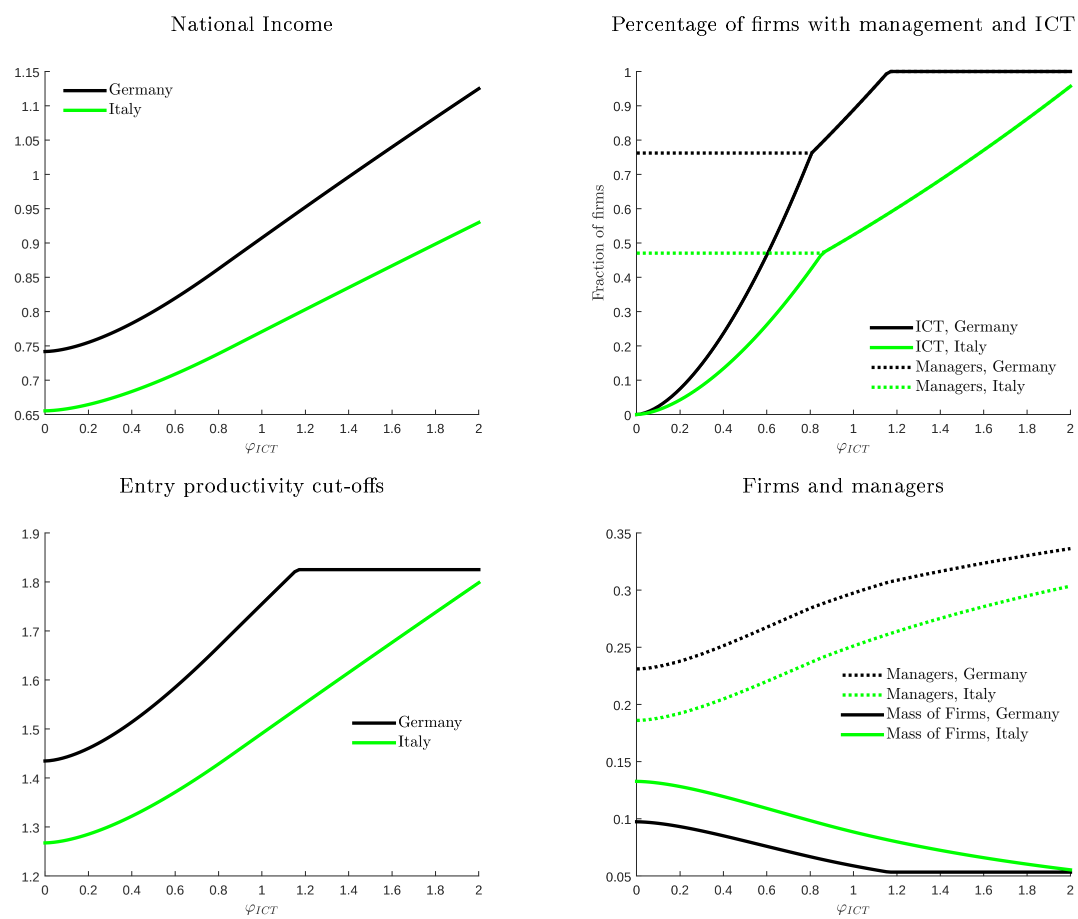
as much in Italy than in Germany, they capture a lower share of aggregate demand, and this allows more low-productivity firms to remain in the market, further depressing aggregate productivity.

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.[18]

Figure 4: The impact of the ICT revolution



[18]The ICT revolution can also be modeled as a drop in f_{ICT} rather than an increase in φ_{ICT}. As shown in the Appendix, most results do not depend on this.

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.

- 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 efficient to concentrate production at a few extremely productive firms, and to allocate most of the labour force to these firms. Thus, the ICT revolution increases average firm size.[19]

- 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 demand labour to pay the fixed cost of ICT), 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 becomes so productive that all firms with managers want to have it.

- 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.[20] Lower adoption of ICT in Italy has two reasons. First, there is a direct effect. Italian managers are less productive, and ICT is management-augmenting. Therefore, 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

[19] 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).

[20] 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.

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.

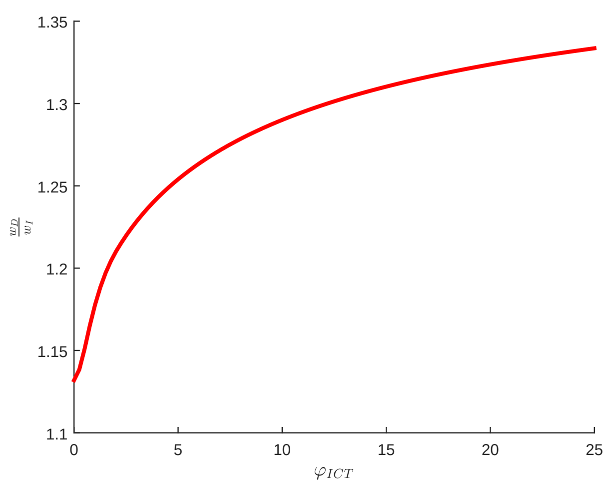
However, does the ICT revolution lead to convergence or divergence in per-capita national incomes between Italy and Germany? This is not obvious. Indeed, several forces are at work.

- **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 productivity 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 shows 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

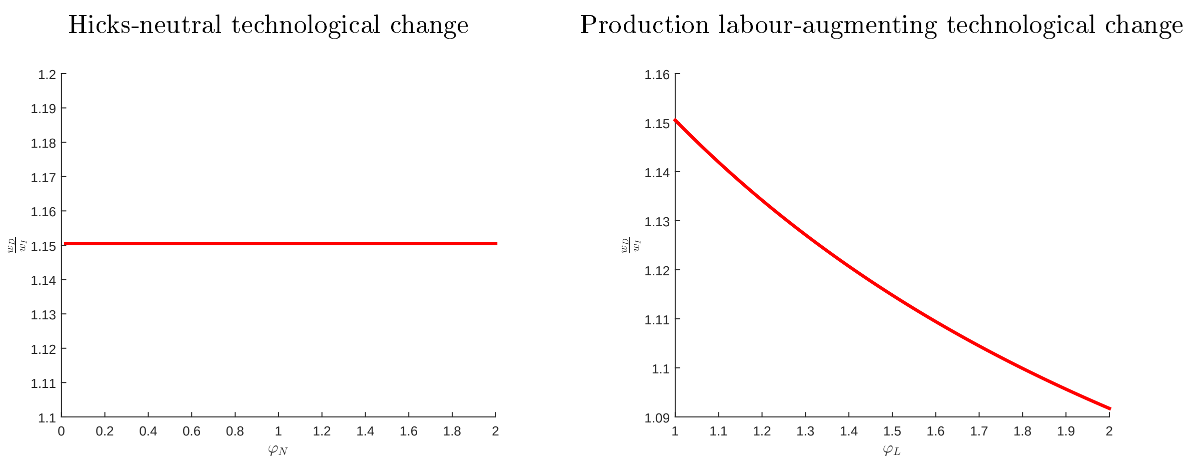


4.4 Comparisons with other types of technological change

The previous section has shown that 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.

In contrast, Figure 6 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 productivity differences for management matter less.

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



This underlines an important insight from our model. It shows that the divergence triggered by the ICT revolution may not only be due to the direct effect of ICT (Italian firms using less hardware and software), but also, and maybe to an even larger extent, to an indirect effect: ICT has increased the importance of a production factor that is supplied less efficiently in Italy. Finally, our model also indicates that the relative performance of Italy in the future may depend very much on the bias of technological change.

5 Firm-level evidence on management and ICT adoption

In this section, we confront some of the model's firm-level predictions to the data, and sketch an outline for a more quantitative approach to come in the future.

5.1 Data sources

We use two firm-level databases for European countries. In order to look at ICT adoption, we use the European "*Community survey on ICT usage and e-commerce in enterprises*". This survey is coordinated by Eurostat, but run by national statistical offices, who also regulate their availability to researchers.[21] We have obtained access to the firm-level data for the survey of 2014, for Italy and for Germany. The survey is based on a representative sample of firms with more than 10 employees,[22] and covers 19,000 firms for Italy and around 7,500 for Germany.

While this survey contains fairly detailed information on ICT adoption, it has little other information about firms. Therefore, we also rely on the EFIGE dataset, which has been assembled in 2009 as the result of a European effort coordinated by the Bruegel institute (see Altomonte and Aquilante (2012)). The survey covered a representative sample of firms with more than 10 employees in seven European countries (including Italy, Germany, France and Spain), and contained questions both about firms' usage of ICT and about their management structure. Furthermore, through linking the original survey to the Amadeus database, provided by Bureau Van Dijk, the dataset also contains a large number of balance sheet variables, allowing to calculate different measures of productivity.

5.2 ICT adoption

We first consider firm-level evidence on ICT adoption, using the Eurostat survey for Italy and Germany. Table 5 reports, in the first two columns, what we see as the most direct counterpart of the model's ICT variable in the data: an indicator of whether the firm employs ICT specialists (i.e., of whether the firm has an ICT department. Overall, 15% of Italian firms employ ICT specialists, against 23% of German firms, a difference in adoption rates of 8 percentage points, or more than 50%.

While our model emphazises the role of firm demand for low ICT adoption, one could imagine in principle that low supply (of ICT-related human capital or infrastructure) plays a role, too. Table 5 provides some preliminary evidence against this alternative explanation. For instance, columns 3 and 4 display the percentage of firms that reported difficulties in recruiting ICT specialists (among those who were on the market for such workers). While 30% of firms reported problems in Italy, 52% did so in Germany, indicating that scarcity of human capital does not seem to be able to explain the ICT adoption gap between both countries. Furthermore, there do not appear to be large cross-country differences in the access to or speed of internet

[21] For further details, see http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Community_survey_on_ICT_usage_in_enterp

[22] National statistical institutes can also choose to survey smaller firms, and both the Italian and the German one do so. However, the Italian statistical institute does not make this data available to researchers, so that we choose to ignore firms with less than 10 employees throughout. Furthermore, due to more stringent data protection regulations, the Italian data contains only very little firm-level information apart from ICT adoption. Therefore, for instance, we cannot observe the actual number of employees and sales of Italian firms, but only dummies for size classes.

connections (Columns 5 through 8). Overall, this evidence suggest that demand factors are key to explain the differences in adoption rates between Italian and German firms.

Table 5: 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.

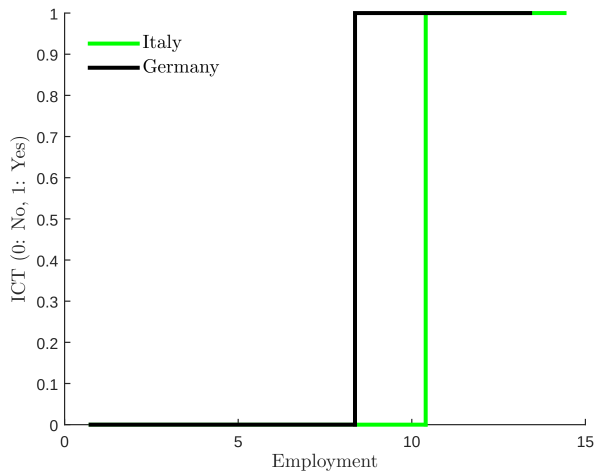
The table also indicates that adoption rates increase with firm size, as measured by the number of employees, going from a minimum of 11% in the smallest size class in Italy to 81% for the largest size class in Germany. This is consistent with our model,[23] as well as with previous evidence.[24] Furthermore, the two effects discussed in Section 4.2 are at work to generate a lower aggregate adoption rate in Italy. First, note that even within size classes (that is, conditional on size, which should be a reflection of productivity), adoption rates are lower in Italy. In the model, this is explained by the direct effect of lower manager productivity, which makes Italian firms less likely to adopt ICT conditional on size. Second, as ICT adoption is increasing in firm size, the more left-skewed size distribution in Italy (which, in the model, is a indirect consequence of lower manager productivity) clearly contributes to the lower overall adoption rate as well.

Finally, there is one last, more specific prediction of the model which can be checked: as illustrated in Figure 7, the difference in ICT adoption rates should be largest for firms of intermediate size. Indeed, in the model, the smallest firms never adopt ICT, while the largest firms always do. Thus, all cross-country differences in adoption rates come from firms with intermediate sizes.

[23] Of course, in the model, adoption is deterministic and strictly increasing in firm size, whereas in reality, we observe differences in adoption for observationally equivalent firms, as well as the fact that some small firms adopt ICT while some larger firms do not. However, it would be 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.

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

Figure 7: Employment and ICT adoption in the model



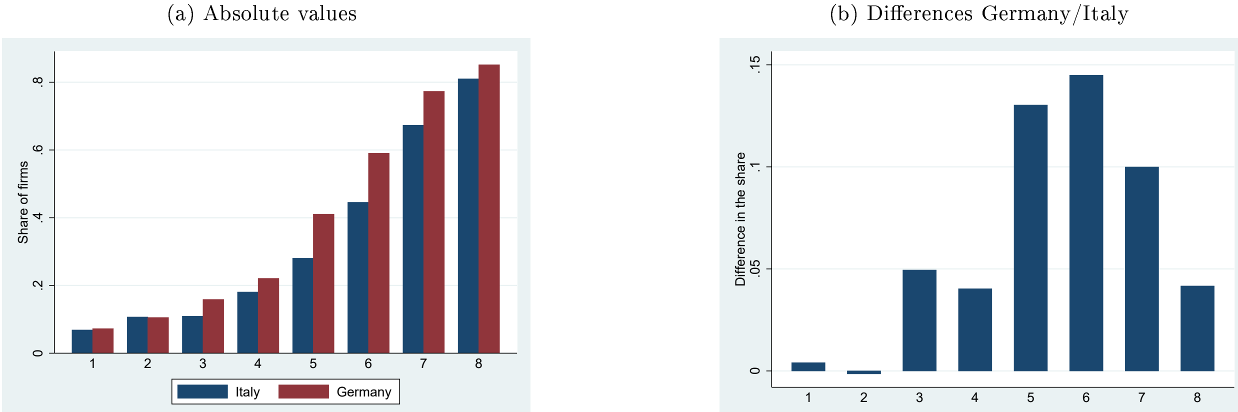
Note: Employment includes workers and managers, but not labour hired to cover fixed costs.

Unfortunately, the employment size classes provided in the Italian data are very coarse. However, there is a somewhat finer disaggregation for sales, distinguishing eight sales classes (and we observe actual sales for German firms). Using this information, Figure 8 shows the share of firms employing ICT specialists by sales class. Panel a) shows absolute values, confirming that ICT adoption increases with firm size. Adoption rates within size classes are 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: while 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 firms with sales between 20 and 50 million euros. Then, they 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=(500'000-999'999), 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).

Table 6: 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

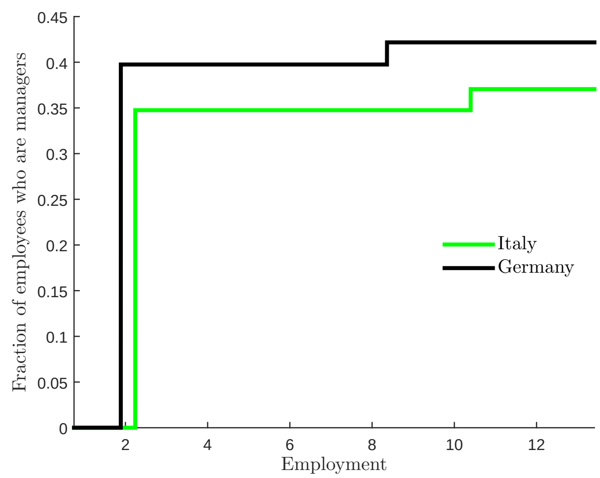
Note: Each cell reports the share of firms that have answered "yes" to the following questions: if the firm uses enterprise resource planning software (ERP, [1]-[2]); if the firm uses Radio-Frequency Identification technology to monitor the production process (RFID, [3]-[4]); if the firm uses Customer 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.

Finally, while ICT is a binary variable in the model, in reality there are of course different ICT technologies that serve different purposes, such as organizational software, software for supply chain management, online sales, websites and social networks. In Table 6 we report the adoption rate of four particular 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. For these technologies, Italian adoption rates are depressed because of the skewed size distribution, but there does not appear to be an effect conditional on size. 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 lens of our model, this results could 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.

5.3 Managers

The key assumption of the our model is that delegation efficiency (and therefore manager productivity) 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

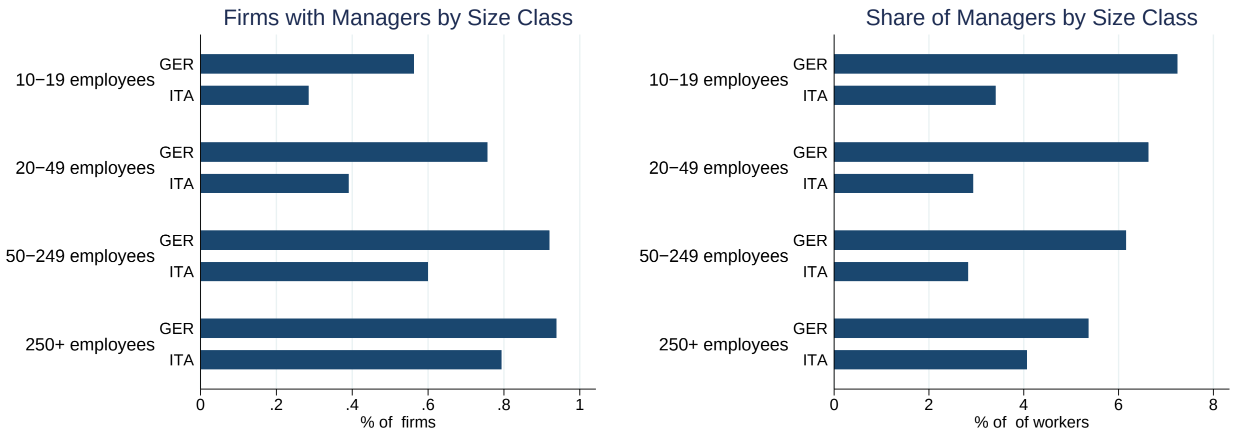


Note: Employment includes workers and managers, but not labour hired to cover fixed costs. The discontinuity in the graph is due to ICT adoption, which creates a discontinuity in the employment distribution.

To look at managers in the data, we use the EFIGE dataset. In the EFIGE survey, firms are asked about the total number of managers they employ, distinguishing between “internal” managers (members of the owner’s family) and “external” managers (non family members). We decide to consider only external managers as the data equivalent of the managers in our model: we think about family members as a way to avoid a more formal management structure in a situation where delegation efficiency is low (that is, we assume that only firms with external managers have paid the fixed cost of management, and implemented a formal management structure).

As Table 7 shows, there are very large differences in the adoption of external management in Italy and Germany. In total, 77% of German firms hire at least one external manager, while this is the case for only 40% of Italian firms. Furthermore, there are large differences in the share of managers in the total workforce of firms, going from on average 6.5% in Germany to 3.1% in Italy. These differences, consistently with the model, are large in essentially any size class.

Table 7: Firms with managers, by size class



So, the data is consistent with large differences in the organizational structure of firms, with German firms being considerably more management-intensive. In the next section, we describe some first evidence for the productivity effects of external managers and ICT, as well as for the management-augmenting character of ICT.

5.4 The productivity effect of ICT and managers

In our model, both the adoption of management and the adoption of ICT raise firms' total factor productivity.[25] Furthermore, we have made the crucial assumption that ICT is management-augmenting technological change, that is, that it boosts productivity more in firms which have adopted management.

In this section, we examine these issues more in detail. In particular, we use existing estimates of firms' TFP in the EFIGE database (computed using the method of Levinsohn and Petrin (2003)) to estimate the following regression

$$\ln(\mathrm{TFP}_i) = \alpha + \beta_1 \mathrm{EM}_i + \beta_2 \mathrm{ShareEM}_i + \beta_3 \mathrm{ICT}_i + \beta_4 \mathrm{EM}_i \cdot \mathrm{ICT}_i + \varepsilon_i, \tag{11}$$

where TFP_i is the Levinsohn-Petrin measure of TFP,[26] EM_i is a dummy for whether the firm has hired external managers, and ICT_i is a dummy for ICT adoption.[27] In the context of the model, β_1 would capture the manager productivity parameter ξ, and β_4 the additional productivity boost due to ICT, $(\xi - 1)(1 + \varphi_{ICT})$.

[25] This refers to total factor productivity computed without taking into account the fixed costs of adoption. It may seem reasonable to assume that in reality, a large part of these fixed costs is paid only once upon adoption, so that it makes sense to compute total factor productivity in later periods without taking them into account.

[26] To control for outliers, we drop the 1st and 99th percentile of the TFP distribution.

[27] In this dataset, we define a firm as an ICT adopter if it has adopted both ICT solutions for internal information management (e.g. SAP/CMS) and for managing sales (suppliers' orders, customer service).

Table 8: Productivity, size and ICT adoption

VARIABLES	(1) TFP	(2) TFP	(3) TFP
EM	0.106***	0.104***	0.092***
	(0.015)	(0.015)	(0.016)
shareEM	0.420***	0.413***	0.416***
	(0.095)	(0.094)	(0.094)
ICT		0.060***	0.023
		(0.013)	(0.021)
EM_ICT			0.056**
			(0.026)
Constant	-0.337***	-0.343***	-0.336***
	(0.028)	(0.028)	(0.028)
Observations	6,576	6,576	6,576
R-squared	0.155	0.158	0.159
Country FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

β_3, in term, would be equal to 0, as firms without management cannot benefit from ICT adoption. The share of external managers in overall employment is added as an additional control.

Table 8, showing the estimates of Equation (11) for a panel of four European countries (Italy, Germany, France and Spain), confirms these predictions. The estimates indicate that adopting external managers raises TFP by around 10%, and adopting ICT adds an additional 6%. Most importantly, ICT adoption in itself gets insignificant once we control for the interaction between ICT and management (which itself is positive and significant). This supports the complementarity between management and ICT that is so important for our theoretical mechanism.

Of course, there are a lot of econometric issues with the estimates of Table 8. Most importantly, all the explanatory variables are correlated with the unobservable exogenous productivity draw A (which enters the error term), and this clearly biases coefficients.

Thus, to improve the empirical evidence and to advance towards providing some quantitative evidence for the mechanisms described by our model, two elements will be key.

- First, we plan to use the structural relationships yielded by the model to establish a clearer mapping between moments and observables in the data and the model's parameters, to eventually be able to do a structural estimation of the latter.

- Second, we then need to carry out the estimation at a country level, in order to confirm that the delegation efficiency in Italian firms is indeed lower than in other countries. Here, there are unfortunately issues with our preferred comparison country, Germany, as the mapping from EFIGE to Amadeus balance sheet data is significantly worse in Germany than in other countries.

Once we have obtained estimates for the key parameters ξ_D, ξ_I and σ, we will be able to quantify how much, according to our model and the data, the ICT revolution has contributed to Italy's divergence. We will also be able to assess whether this divergence is mostly due to the direct effect of ICT adoption, or mostly to the indirect effect of making managers a more important production factor.

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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* $A_E^* = A_M^* = A_{ICT}^* = \frac{1}{\varphi_N \varphi_L \widetilde{\xi}_{ICT}} \left(\frac{f + f_M + f_{ICT}}{\frac{B}{w}} \right)^{\frac{1}{\varepsilon-1}}$.