The IT Revolution and Southern Europe's Two Lost Decades*

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Abstract

Since the middle of the 1990s, productivity growth in Southern Europe has been substantially lower than in other developed countries. In this paper, we argue that this divergence was partly caused by inefficient management practices, which limited Southern Europe's gains from the IT Revolution. To quantify this effect, we build a multi-country general equilibrium model with heterogeneous firms and workers. In our model, the IT Revolution generates divergence for three reasons. First, inefficient management limits Southern firms' productivity gains from IT adoption. Second, IT increases the aggregate importance of management, making its inefficiencies more salient. Third, IT-driven wage increases in other countries stimulate Southern high-skill emigration. We calibrate our model using firm-level evidence, and show that it can account for 35% of Italy's, 47% of Spain's and 81% of Portugal's productivity divergence with respect to Germany between 1995 to 2008.

Keywords: TFP, Southern Europe, Divergence, IT, Technology adoption, Management.

JEL Codes: L23, O33

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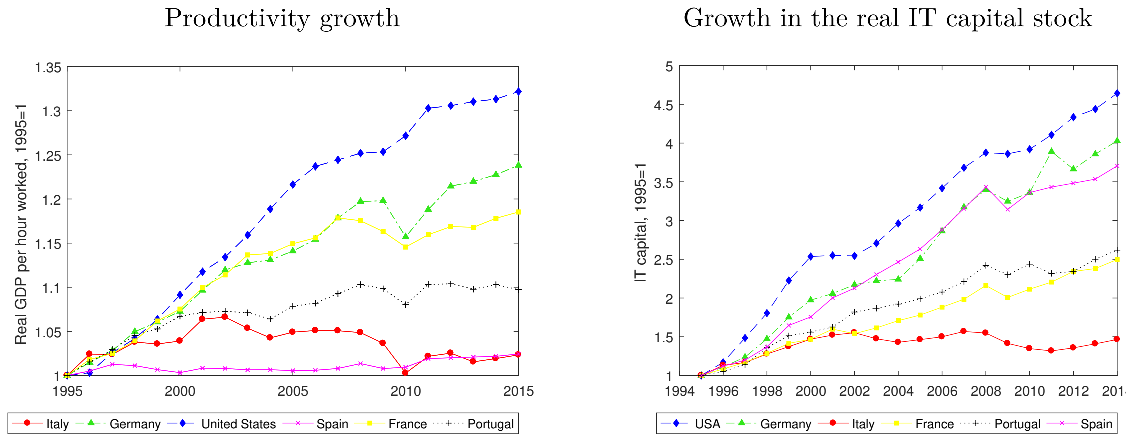
1 Introduction

Since the middle of the 1990s, productivity growth in Southern Europe has been substantially lower than in other developed countries. The left panel of Figure 1 illustrates this by plotting aggregate productivity, measured as real GDP per hour worked (net of non-IT capital deepening), for six OECD countries.[1] Between 1995 and 2015, productivity grew by only 0.1% per year in Italy and Spain and by 0.5% per year in Portugal, while it grew by 1.1% per year in Germany and by 1.4% per year in the United States.

Figure 1: Productivity growth and IT capital across the OECD



Source: OECD and EU KLEMS. See Appendix A for further details.

The striking divergence of Southern Europe coincides with the rise of information technology (IT), which was a major driver of productivity growth in the leading economies (Fernald, 2014, Gordon, 2016).[2] In Southern Europe, this IT Revolution made relatively little headway. The right panel of Figure 1 indicates that between 1995 and 2015, the real stock of IT capital increased by a factor of 4.6 in the United States and by a factor of 4 in Germany, but only by a factor of 1.5 in Italy and a factor 3.7 in Spain. This suggests two observations. First, the diffusion of IT in

[1]The data comes from the OECD Productivity Database, which decomposes growth in real GDP per hour worked into changes in total factor productivity (TFP), IT capital deepening and non-IT capital deepening. Our preferred measure of productivity growth is the sum of the two former components. This measure has the advantage to control for changes in the capital stock, while still taking into account the effect of IT capital. Appendix A provides further details on the data and replicates Figure 1 for changes in TFP (see Figure A.2).

[2]In the 1980s, Robert Solow famously stated that "*you can see the computer age everywhere, except in the productivity statistics*" (Solow, 1987). However, Byrne et al. (2013), Fernald (2014) and Gordon (2016), among others, show that towards the middle of the 1990s, IT caused an acceleration of US productivity growth that lasted for at least a decade. US productivity has slowed down since, but even its low growth after 2005 substantially exceeds that of Southern Europe.

Southern Europe was limited. Second, even in countries which had somewhat faster growth in IT capital (such as Spain), this seems to have had a negligible impact on productivity. However, why did the IT Revolution have a lower impact in Southern Europe than elsewhere?

An extensive empirical literature has documented that IT adoption requires complementary changes in firm organization (Brynjolfsson and Hitt, 2000) and that it induces higher productivity gains in better-managed firms (Garicano and Heaton, 2010, Bloom et al., 2012). Building on the World Management Survey (WMS) developed by Bloom and Van Reenen (2007), we document that Southern European firms perform worse for a number of management efficiency measures. We also provide additional quantitative evidence for the complementarity of IT and efficient management practices, in line with the results of the earlier literature. This suggests that inefficient management practices may be responsible for Southern Europe's divergence, as they lowered the productivity gains from IT adoption for Southern European firms and reduced their IT demand. This, in turn, depressed demand for the high-skilled labour necessary to operate the new technology and may have stimulated high-skilled emigration, another striking trend during the divergence period.

The main contribution of our paper is to provide a quantitative model to analyse these trends. The model shows that many features of Southern European economies can be explained by a single factor, inefficient management. Most importantly, it identifies the exact channels through which inefficient management interacted with the IT Revolution to create divergence, and allows us to assess their quantitative importance.

The model considers two regions, which we call North and South. In each region, a continuum of workers choose whether to supply high or low-skilled labour in their home region or abroad. Their choices depend on education and migration costs, which are heterogeneous across workers, and on wage levels.

Production is carried out by a continuum of firms, which produce differentiated nontradable goods under monopolistic competition. Firms pay an entry cost to draw an idiosyncratic productivity from an exogenous distribution, and then decide whether to exit or to stay in the market. In the latter case, they can produce with a basic technology or adopt more advanced technologies, such as management and IT. Advanced technologies increase productivity with respect to the basic one, but they also have higher fixed costs and require more high-skilled workers. Throughout, we assume that the North and the South are exactly identical, except for the fact that the efficiency of management practices (a parameter which determines the productivity increase of a firm adopting management) is lower in the South. We also assume that IT and efficient management are complements, in line with the literature and with our own empirical results. That is, IT increases firm productivity more in a region with more efficient management practices. In equilibrium, firms sort according to their idiosyncratic productivity draws: the firms with the highest draws adopt both management and IT, firms with intermediate draws adopt only management, firms with low draws produce with the basic technology, and the firms with the lowest draws exit.

To analyse the impact of the IT Revolution, we compare our model's equilibrium without IT (representing the situation before the IT Revolution) to an equilibrium with IT (representing the situation after the IT Revolution). Before the IT Revolution, the South already differs from the North. Inefficient management practices lower management adoption and competitive pressure. Thus, more firms are able to remain in the market, and the average firm is both smaller and less productive. Demand for high-skilled labour is depressed, lowering the number of high-skilled workers and the skill premium, and leading some high-skilled workers to emigrate. As a result, output and aggregate productivity are lower in the South.

The IT Revolution amplifies these pre-existing differences through three channels. First, the IT-management complementarity lowers Southern firm-level productivity gains from IT adoption. This directly lowers IT adoption rates and aggregate productivity growth.[3] Second, the IT Revolution increases the employment share of firms using management. This generates divergence through a composition effect. Southern firms are as efficient as their Northern counterparts for the basic technology, but less efficient for management. Thus, as the IT Revolution increases the aggregate importance of management, the Southern disadvantage becomes more salient. Third, the IT Revolution increases Northern high-skilled wages more than Southern ones. This increases high-skilled emigration, which amplifies divergence by increasing the education costs of the marginal high-skilled worker in the South.

We use our model for a quantitative analysis of the IT Revolution's role for the divergence between Southern Europe and Germany between 1995 and 2008.[4] We calibrate the most crucial parameters

[3] Adoption rates are further depressed because (as a consequence of inefficient management) the average Southern firm is smaller than the average Northern firm, and thus less likely to pay the fixed cost of IT adoption.

[4] Southern Europe was hit much harder by the financial crisis starting in 2008. This may have affected productivity

using evidence from the WMS, growth accounting, and our micro-level evidence on the link between management, IT and firm productivity. The remaining parameters are set to match a series of moments for Germany in 2008. In our baseline calibration, the IT Revolution increases productivity by 11.1% in Germany, 5.9% in Italy, 2.5% in Spain, and 3.4% in Portugal. It therefore accounts for 35% of the Italian, 47% of the Spanish, and 81% of the Portuguese divergence with respect to Germany. Divergence is mainly driven by lower firm-level productivity gains from IT adoption, compounded by lower adoption rates. The higher aggregate importance of management also makes a substantial contribution. High-skilled emigration is multiplied by a factor of three as a consequence of the IT Revolution, but this has a relatively small impact on aggregate productivity.

Finally, we use our model to evaluate the effects of subsidy policies. Subsidizing IT and management adoption actually lowers Southern European productivity even further, with the negative impact falling most heavily on low-skilled workers. Subsidizing education also has negative effects, as it is effectively a transfer to the North, which reaps the benefits from the subsidy through high skilled workers' migration. These results should be taken with a grain of salt, as we abstract from market failures that might result in suboptimal levels of IT adoption or education. Nevertheless, they show that low IT adoption and low education levels are a symptom rather than the cause of low productivity growth in Southern Europe. Long-term policies should focus instead on the underlying cause that lowers firms' demand for IT and high-skilled labour, namely inefficient management.

Our analysis is closely related to Bloom et al. (2012) and Pellegrino and Zingales (2017). Bloom et al. (2012) show that subsidiaries of US multinationals in Great Britain use IT more intensively and more efficiently than other firms operating in the country, and that this is due to their more efficient management practices. They conjecture that this finding may explain divergence between Europe and the United States since the middle of the 1990s, but do not provide a detailed quantitative assessment of this claim. Pellegrino and Zingales (2017) empirically test several hypotheses for the Italian slowdown, concluding that the most likely cause is the "familism and cronyism" of Italian firms, making them unable to benefit from the IT Revolution. Our main contribution with respect to these studies is to provide an analysis based on a general equilibrium model rather than relying on reduced-form regressions. We show that this difference matters quantitatively, because it allows us

and IT adoption for cyclical reasons that are not captured by our analysis. However, as a robustness check, we repeat our analysis for the full period 1995-2015. This yields similar results, as we discuss in greater detail in Section 4.

to take into account some crucial features of reality such as firm heterogeneity and the endogeneity of IT adoption decisions. Moreover, our model emphasizes some divergence channels which have not been considered before, such as the increase in the aggregate importance of management or the role of high-skilled emigration.

Garicano (2015) has also stressed the role of IT for Southern Europe's slowdown, arguing that small firm size due to size-dependent regulations limited IT adoption. However, the evidence on size-dependent regulations is mixed: while Garicano et al. (2016) show that they matter in France, Schivardi and Torrini (2008) argue that their role in Italy is marginal. In our model, firm size is depressed because of inefficient management, and this further lowers IT adoption. Other studies have proposed different explanations for Southern Europe's divergence. For instance, Gopinath et al. (forthcoming) argue that misallocation of capital inflows slowed down TFP growth in the manufacturing sector.[5] Our results are complementary to their findings. Indeed, we find that the IT Revolution does not account for all of Southern Europe's divergence. Thus, there must have been other drivers, misallocation of capital being one of them. Focusing on Italy, Daveri and Parisi (2010) have instead stressed the role of labour market reforms.[6]

More generally, our paper builds on the extensive literature on the IT Revolution (see, among many others, Stiroh, 2002, Syverson, 2011 and Akerman et al., 2015). It also relates to a number of studies on the role of management efficiency for cross-country TFP differences (Guner et al., 2015, Akcigit et al., 2016, Bloom et al., 2016), which however do not consider IT. Finally, our model shares some features with Bustos (2011), an extension of the classic Melitz (2003) framework.

The remainder of the paper is structured as follows. Section 2 presents some basic stylized facts on management practices, IT adoption and emigration in Southern Europe, including microeconometric evidence that will inform our calibration. Section 3 sets up and solves a model with firm and worker heterogeneity which identifies the main channels for divergence. Section 4 describes our calibration and the model's quantitative implications, and Section 5 concludes.

[5]Related empirical studies focusing on Italy (Calligaris, 2015, Calligaris et al., 2016) or Spain (Garcia-Santana et al., 2015) reach similar conclusions. A general finding of these studies is that the Southern European slowdown cannot be explained by its sectoral structure. Productivity growth was low in virtually every sector, pointing to a more general common cause.

[6]It has long been recognized that Southern Europe suffers from a number of institutional imperfections. However, in spite of these, it grew very rapidly between 1945 and 1995. Thus, the later divergence must be due to a major change in the economic environment in the middle of the 1990s. In our theory, this change was the IT Revolution, which boosted the importance of management practices, while for Gopinath et al. (forthcoming), it was the creation of the Euro, which led to capital inflows that were inefficiently allocated to low-productivity firms.

2 Management practices, IT and emigration in Southern Europe

Our analysis rests on two key assumptions: countries differ in the efficiency of firms' management practices, and efficient management practices and IT are complements. In this section, we provide evidence for both assumptions, quantify them, and discuss their implications for productivity growth and high-skilled migration.

2.1 Management practices

While the importance of management for firm productivity has long been recognized, research on the subject has been constrained by the lack of quantitative evidence. In the last decade, however, measurement of management practices has greatly improved, particularly thanks to the World Management Survey (WMS), developed by Nick Bloom, Raffaella Sadun and John Van Reenen. The WMS covers 28 countries, and its baseline version, which we use in this paper, focuses on manufacturing firms of intermediate size (between 50 and 5.000 employees). Data is collected in telephone interviews, during which a trained interviewer asks plant managers about various management practices (for instance, the setting of goals, performance measurement, or human resource management), and then scores these on a scale ranging from 1 to 5 (lower scores indicating worse practices).[7] Following standard practice, we define a "management score" at the firm level as the arithmetic average of the scores for the single questions, standardized to have mean 0 and standard deviation 1 across the sample. Panel A of Figure 2 plots the average value of this score for a set of OECD countries.

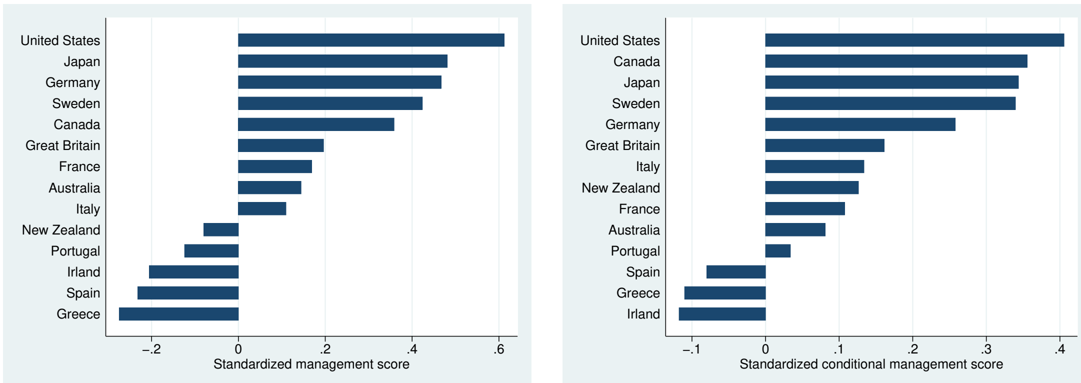
This figure reveals substantial cross-country differences in management scores. In particular, Southern European countries such as Italy, Spain, Portugal and Greece have substantially lower scores than Northern European countries, the United States, Canada and Japan. This pattern could in principle be driven by composition effects. Indeed, Appendix Table A.1 shows that average firm size differs substantially across countries, and larger firms might have better higher scores. Countries also differ in terms of sectoral specialization. However, Panel B of Figure 2 reports average management scores after controlling for 20 two-digit sector fixed effects and for firm size (measured by employment). The pattern is very similar, suggesting that differences in management scores are

[7] The WMS is described in greater detail in Appendix A, which also contains summary statistics for every country. We are grateful to Bloom, Sadun and Van Reenen for providing us with the non-anonymized version of the data.

not only driven by composition, but reflect some other country attributes.

Figure 2: Management efficiency in OECD countries

Panel A: Management score Panel B: Conditional management score



Source: Authors' calculations based on WMS data. For details, see Appendix A. The conditional management score is the residual of a regression of firm management scores on sector fixed effects and the natural logarithm of employment.

A growing body of experimental and quasi-experimental studies show that differences in management scores matter, as better management practices have a causal impact on firm productivity.[8] Reviewing the evidence, Bloom et al. (2016) conclude that a unit increase in the standardized management score increases firm productivity by around 10%. This estimate will be an important input in our calibration.

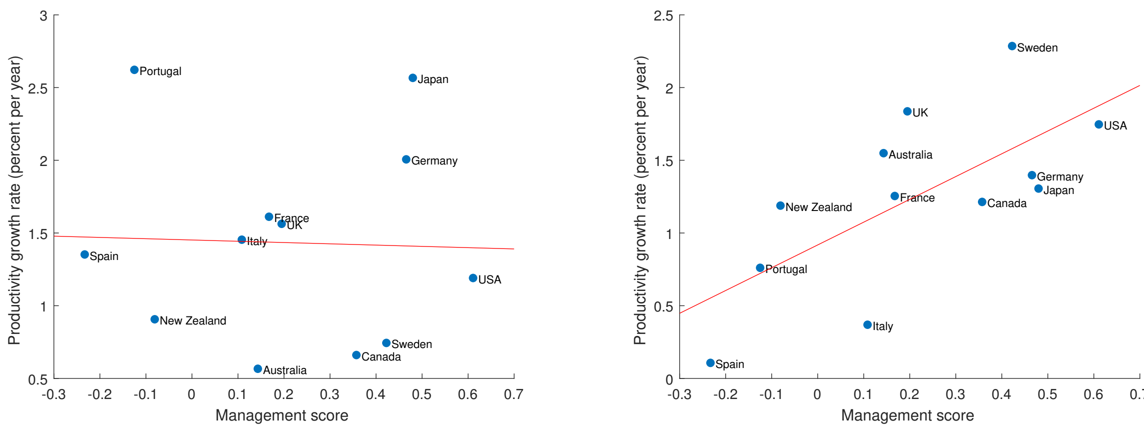
In our theoretical analysis, we model management as a production technology improving firm productivity. To keep the analysis tractable, we make two simplifying assumptions. First, we assume there is no within-country variation in management practices. Of course, there is substantial within-country dispersion in the data. However, following Melitz (2003), our model will already assume that firms are heterogeneous with respect to their idiosyncratic productivity. Adding a second layer of firm heterogeneity makes the analysis substantially more complicated, and arguably would only have a second-order effect on our results. Indeed, in Appendix A, we show that the distribution of management scores is similar across countries, so that focusing on its mean accounts for the most important cross-country differences. Second, we take cross-country differences in management practices as exogenously given. The literature has investigated some potential determinants, stressing

[8] Bloom et al. (2013) and Bruhn et al. (forthcoming) set up field experiments in India and Mexico in which entrepreneurs are randomly selected into a managerial training scheme. Giorcelli (2016) exploits a natural experiment due to an unexpected budget cut of a program within the Marshall plan offering management-training trips to the United States for Italian managers.

among others the role of ownership and control. For instance, firms which are fully managed by the owning family are known to have sub-par management scores (Bloom and Van Reenen, 2007), and Bugamelli et al. (2012) show that such firms are more common in Southern Europe. Differences in ownership and control, in turn, can be traced back to institutional differences (for instance, labour laws or judicial systems), or differences in the human capital of managers. All these causes are likely to be persistent, and we therefore consider management practices as a quasi-fixed country attribute.[9]

Figure 3: Management scores and productivity growth before and after the IT revolution

Panel A: 1985-1995 Panel B: 1995-2008



Source: OECD, WMS. Productivity growth is growth in real GDP per hour worked net of non-IT capital deepening (see Figure 1). These graphs omit Greece (which has no productivity data) and Ireland (see discussion in Appendix A).

Do these differences in management practices matter for Southern Europe's divergence? Figure 3 provides some preliminary evidence on this point. Panel A shows that before the IT Revolution, there was no correlation between management scores and productivity growth. However, Panel B shows that this changed radically around 1995, and a strong positive correlation emerged. Thus, inefficient management practices started to become a drag on growth with the beginning of the IT Revolution. This supports our story, namely that IT and management are complements and that this can explain Southern European divergence after the start of the IT Revolution in 1995.[10]

[9]Systematic measurement of management practices is too recent to study their evolution over time. Giorcelli (2016) shows that in the 1950s, US officials claimed that European firms lacked a "managerial mentality" and were very inefficiently managed. She also finds strong and persistent effects on productivity for the firms whose managers took part in management-training trips to the US, compared to those which did not. This suggests that heterogeneity in management practices was already large in the 1950s, and that it persisted over time.

[10]In this paper, we define the IT Revolution as the IT-driven acceleration in frontier (US) productivity growth. Byrne et al. (2013) date this event in 1995, Fernald (2014) and Gordon (2016) in 1996.

Our productivity measure shown in Figure 3 (real GDP per hour worked, net of non-IT capital deepening) can be decomposed into the relative contributions of IT capital deepening and TFP. This indicates that most of the cross-country differences in productivity growth after 1995 are explained by TFP and not by IT capital (see Appendix A). At first sight, this may seem to indicate that the IT Revolution cannot explain differences in productivity growth. However, it is well known that standard growth accounting methods cannot fully capture the contribution of IT capital to productivity growth: they miss the effect of IT-induced investments in intangible capital and changes in firm organization, which often occur with considerable lags (Basu and Fernald, 2008), as well as the externalities and spillovers of the new technology (Pellegrino and Zingales, 2017). Furthermore, TFP growth includes productivity growth in IT-producing industries, which should arguably be attributed to the IT Revolution. For all of these reasons, the complementarity between management practices and IT will show up in TFP, and can potentially explain the large cross-country differences in TFP growth. In the next section, we discuss the existing evidence for this complementarity, and provide additional quantitative results that will inform our model's calibration.

2.2 Complementarities between management and IT

2.2.1 The existing empirical evidence

An extensive empirical literature on the IT Revolution argues that IT needed organizational capital investments to develop its full potential (Brynjolfsson and Hitt, 2000). Even more importantly, it shows that efficient management practices increase the productivity gains from IT adoption. For instance, Bresnahan et al. (2002) use a panel dataset for the US to show that the productivity impact of IT is largest in firms with high levels of human capital or a decentralized work organization. Garicano and Heaton (2010) argue that IT investments in US police departments improved productivity only if they were "*complemented with particular organizational and management practices*". Bloom et al. (2012) show that subsidiaries of US multinationals in Great Britain use IT more and more efficiently than local firms, and attribute this to their superior management practices. They also provide evidence of IT-management complementary using a panel of European firms.

These findings suggest that countries with less efficient management practices should have benefited less from the IT Revolution, in line with the evidence shown in Figure 3. In the next sections, we present some stylized facts on IT adoption and regression evidence for its productivity impact which further support this claim.

2.2.2 IT adoption across Europe

To document IT adoption patterns, we rely on the 2014 wave of the European "*Community survey on ICT usage and e-commerce in enterprises*". This survey, coordinated by Eurostat and run by national statistical offices, is based on a representative sample of firms with more than 10 employees, stratified by sector, size and geographical area. We obtained access to the micro data for Germany and Italy, the two largest economies in Northern and Southern Europe.[11] The survey covers around 19.000 firms in Italy and 7.500 firms in Germany.

Table 1: Adoption rates for various IT technologies in Italy and Germany

	IT specialists		**ERP**		**CRM**		**SCM**	
	[1] ITA	[2] GER	[3] ITA	[4] GER	[5] ITA	[6] GER	[7] ITA	[8] GER
Size class								
10-49	11	15	34	33	17	25	15	20
50-99	35	39	58	60	27	36	21	33
100-249	58	57	70	68	31	40	23	38
250+	74	81	79	85	36	48	36	57
Total	15	23	38	41	19	28	16	24

Source: Research Data Centre of the Federal and Regional Statistical Offices, "*Nutzung von Informations - und Kommunikationstechnologien (IKT) in Unternehmen 2014*" (Germany), ISTAT (Italy), own calculations. All numbers shown correspond to the percentage of firms of a given size class which use the indicated technology. These statistics use survey weights. For clarity, we report unconditional summary statistics, but all results are confirmed when we control for sectoral and geographical dummies.

The generic term "IT" refers to a large array of different technologies, including both hardware and software. Table 1 shows adoption rates for four different measures of IT, indicating the fraction of Italian and German firms that employ IT specialists (that is, workers for whom IT and information systems management represent the main occupation), or use software for enterprise resource plan-

[11] We focus only on these two countries because access to the data requires a formal application at each national statistical office, with access rules differing by countries.

ning (ERP), customer relations management (CRM) and supply-chain management (SCM). Italian adoption rates are lower for all four measures. Part of this is due to a composition effect: smaller firms are less likely to adopt IT, and the average Italian firm is smaller than the average German one.[12] However, this is not the only difference between the two countries: for most technologies, there are also substantial differences within size classes.

Together with the evidence on IT capital in Figure 1, these adoption rates show that IT is less diffused in Southern Europe. A priori, this could be due to problems relating to IT supply, such as a low supply of IT-savvy workers or deficient infrastructure. However, the survey provides some evidence against these explanations. Indeed, it indicates that only 30% of Italian firms that wanted to hire IT specialists reported problems in doing so, while the corresponding number for Germany was 52%. Furthermore, roughly all firms from both countries had access to the internet in 2014, at comparable speeds. Details for these survey questions are provided in Appendix A.

Thus, low IT diffusion in Southern Europe seems to be due to low IT demand rather than low IT supply. This is consistent with our narrative: if IT and efficient management are complements, then less efficient management practices lower the productivity gains from IT and therefore firms' adoption incentives. In the next section, we provide more evidence for this crucial claim.

2.2.3 Productivity effects of management and IT adoption

To study the complementarity between management practices and IT, we construct a firm-level dataset that matches three sources of information. To compute productivity, we use accounting data from the Bureau Van Dijk database. Data on management practices are from the WMS discussed above. Finally, IT adoption indicators are from Harte-Hanks (HH in what follows), a US consulting firm which surveys production sites to assess the adoption rates of a large class of hardware and software items.[13] We concentrate on software adoption in our analysis, but our results turn out to be remarkably similar to the ones of Bloom et al. (2012), who study the complementarity between management practices and hardware adoption (measuring IT as computers per worker).

HH classifies software into 14 different categories (including ERP, SCM, Communication software,

[12] This may be due to fixed adoption costs, which are present in our model. Other studies also find a positive correlation between size and IT adoption (see Fabiani et al. (2005) for Italy and Bayo-Moriones and Lera-Lopez (2007) for Spain).

[13] We thank Friedrich Kreuser for systematizing the large and complex HH database and sharing it with us. Further information on the datasets is provided in Appendix A.

Office applications, Storage, Security etc.). For each item, HH gives the number of production sites that use the software, and we define a firm-level adoption rate as the percentage of sites of the firm which use the software. We use two measures of IT adoption. Our main measure is the simple average of adoption rates for all 14 software categories, which is intended to capture the firm's overall IT adoption. Furthermore, we also consider a summary indicator for the adoption of ERP software. This software is closely related to human resources management, which has been identified as an area in which IT had a particularly large impact. The survey reports both a general ERP software and specific applications within this general category, such as Supply Chain Management or Sales Force Management. We construct an indicator for the general software and one for the specific ones, and take the average of the two as our summary measure.

The three datasets have different time structures. The accounting data are available annually. Firms in the WMS survey can be surveyed more than once: approximately half of the firms have been surveyed once, 34% twice, and 16% three times or more. To maximise coverage, we take the average value of the management score across surveys as the (fixed) indicator of managerial efficiency for each firm. HH surveys firms repeatedly, but with gaps. To maximise coverage and to take into account the trend in the diffusion of IT, we fill the gaps by taking a linear interpolation at the firm level. We end up with a sample of around 10,500 firm-year observations, corresponding to 1,361 firms. Observations are from nine OECD countries: France (with 1,128 observations), Germany (1,011), the United Kingdom (2,278), Italy (1,727), Poland (474), Portugal (503), Spain (578), Sweden (1,209) and the United States (1,732). The average value for our overall software indicator is 0.32 (s.d. 0.21), while it is 0.43 (s.d. 0.33) for the ERP indicator.

We run the following regression:

$$\ln\left(\frac{VA}{L}_{ijkt}\right) = \beta_0 + \beta_1 IT_{ijt} + \beta_2 IT_{ijt}\cdot MAN_{ij} + \beta_3 MAN_{ij} + \beta_4 \ln\left(\frac{K}{L}_{ijkt}\right) + \beta_5 \ln\left(L_{ijkt}\right) + \nu_{ijkt}, \quad (1)$$

where $\frac{VA}{L}_{ijkt}$ is value added per worker of firm i in country j and sector k at time t, IT_{ijt} is the indicator of IT adoption, MAN_{ij} is the (standardized) management score, $\frac{K}{L}_{ijkt}$ is capital per worker, and L_{ijkt} is the number of workers. We always include country, sector (two-digit SIC) and time dummies, and cluster standard errors at the level of the firm.

The first column of Table 2 shows the results of the specification for the general measure of IT adoption. We find that labour productivity is positively related to IT, and that firms with higher management scores are more productive, consistent with the evidence reviewed above. More importantly, the interaction between the management score and IT adoption is positive and significant at the 10% level. To give a sense of the size of the effect, recall that the standard deviation of the management score is 1 and that of IT adoption is 0.21. Therefore, increasing IT adoption by one standard deviation is related to a 1.9% higher productivity increase in a firm with a one standard deviation higher management score. Finally, labour productivity increases with capital intensity and decreases mildly with size.

Table 2: Productivity, management and IT

	IT adoption indicator			
	[1]	[2]	[3]	[4]
	Overall		ERP	
IT	0.085*	-0.000	0.034	0.003
	(0.050)	(0.032)	(0.034)	(0.023)
IT·Man	0.091*	0.067**	0.081**	0.055**
	(0.055)	(0.033)	(0.033)	(0.026)
Man	0.055**		0.049**	
	(0.025)		(0.023)	
$\frac{K}{L}$	0.233***	0.130***	0.234***	0.130***
	(0.019)	(0.016)	(0.019)	(0.016)
L	-0.040*	-0.207***	-0.041*	-0.207***
	(0.021)	(0.036)	(0.021)	(0.036)
Firm FE	NO	YES	NO	YES
Observations	10,479	10,260	10,479	10,260
R-squared	0.428	0.813	0.428	0.813

Note: The dependent variable is value added per worker. All regressions include country, sector and year fixed effects. Odd columns also include firm fixed effects. Standard errors clustered at the firm level in parentheses. $^{*}: p < 0.10$, $^{**}: p < 0.05$, $^{***}: p < 0.01$.

Needless to say, these estimates cannot be interpreted causally: IT adoption is likely to be related to unobserved heterogeneity not accounted for by the management score. As a further control, we thus introduce firm fixed effects in Column [2]. This implies that we can no longer estimate the coefficient of the management score, as the latter does not vary within-firm. In this specification, the coefficient on IT adoption becomes essentially zero, while the interaction with the management score decreases from 0.091 to 0.067, but becomes significant at the 5% level. Thus, our results cannot be explained by some fixed firm attribute: when a firm adopts more IT, its productivity gains are larger if it has more efficient management practices.

In Columns [3] and [4], we repeat the same regressions using our measure of ERP adoption. Results are even stronger than those for the general indicator, consistent with the notion that management-IT complementarities are particularly important for ERP software. In particular, we find that increasing ERP adoption by one standard deviation is related to a 2.7% higher productivity increase in a firm with one standard deviation higher management score. Overall, our evidence thus supports the assumption that efficient management practices and IT adoption are complements.

2.3 High-skill migration

To conclude this section, we briefly discuss another striking trend in Southern Europe over the last two decades, high-skilled emigration. Table 3 illustrates high-skilled migration patterns by using the first and the latest edition of the Database on Immigrants in OECD countries (DIOC), referring to the years 2000 and 2010. High skilled individuals are those with a tertiary degree. We restrict our attention to migration between Southern Europe (Italy, Spain and Portugal) and the "North", which we define as the rest of the G7, in order to abstract from developing countries. We focus on flows rather than stocks, and therefore only consider recent migrants, who arrived in their country of residence at most five years before the survey.

Table 3: High-skilled migration flows between Southern Europe and the North

		2000			2010		
		absolute	% of high-sk.	% of pop.	absolute	% of high-sk.	% of pop.
North	Immigration	56452	0.06%	0.01%	132196	0.12%	0.03%
	Emigration	48838	0.06%	0.01%	70408	0.06%	0.02%
	Net	7614	0.01%	0.00%	61788	0.05%	0.02%
Southern Europe	Immigration	48838	0.48%	0.06%	70408	0.45%	0.08%
	Emigration	56452	0.55%	0.06%	132196	0.84%	0.15%
	Net	-7614	-0.07%	-0.01%	-61788	-0.39%	-0.07%

Source: OECD and authors' calculations. Migrants are defined with respect to the two regions: thus, immigrants in the North only refer to Southern Europeans, ignoring all other nationalities. For further details, see Appendix A.

In 2000, net high-skilled migration was already negative for Southern Europe: there were around 8,000 more Southern Europeans leaving for the North than Northerners arriving in Southern Europe. These numbers were however relatively small, both with respect to the overall and the high-skilled population. During the 2000s, there has been a massive acceleration: in 2010, the net outflow of high-skilled people from Southern Europe was 8 times higher in absolute numbers and 5 times higher as a percentage of the high-skilled population. Importantly, this outflow is not just driven by the Eurozone crisis: our data for 2010 refer to migration flows for 2006-2010, and the crisis-driven outflows only started at the very end of this period.[14] In our model, we argue that this acceleration can be interpreted as an endogenous consequence of Southern Europe's divergence, as skilled workers were attracted by higher wages in countries exploiting the IT Revolution more successfully. The stylized facts presented in this section are the main building blocks of our argument. In the next section, we develop a model that ties them all together and allows for a quantitative analysis.

3 A model of the IT Revolution

We build a simple general equilibrium model of IT adoption. The model analyses two regions which only differ with respect to their management efficiency, and compares them in an equilibrium without IT (before the IT Revolution), and in an equilibrium with IT (after the IT Revolution).

3.1 Assumptions

3.1.1 Workers

We assume that the world is composed of a continuum of infinitesimally small countries of two types, Northern (N) and Southern (S). As assumptions are symmetric across countries, we drop country superscripts whenever this does not cause confusion. Each country is populated by a unit mass of workers who consume a unique final good and do not experience any disutility of labour. Workers have heterogeneous types j, indexed on $[0, 1]$, and need to make an occupational choice. A worker of type j can supply either one unit of low-skilled labour or j^{ν_1} units of high-skilled labour

[14] In Italy, the crisis led to a further acceleration of outflows in 2010 (Anelli and Peri, 2017). In Spain, where a large boom between 1995 and 2007 triggered an immigration wave, net outflows only started around 2012 (Izquierdo et al., 2015). Accordingly, Table A.4 in Appendix A shows that the emigration dynamics until 2010 are mainly driven by Italy and Portugal. The Italian brain drain and its consequences are analysed in Becker et al. (2004), Anelli and Peri (2017) and Anelli et al. (2017).

if she stays in her home country. Alternatively, she can supply $j^{\nu_1+\nu_2}$ units of high-skilled labour if she emigrates to another country. Low-skilled workers cannot emigrate.[15] Note that both education (that is, becoming high-skilled) and emigration reduce the worker's effective labour supply. The level of this cost is pinned down by the worker's type and by the positive parameters ν_1 and ν_2.

3.1.2 Firms and technologies

In each country, the final good is assembled by a continuum of perfectly competitive firms from a mass M of nontradable intermediates, with the production function

$$Y = \left(\int_0^M y(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad \text{with } \varepsilon > 1. \tag{2}$$

Intermediates are produced under monopolistic competition. A firm can enter the market by employing f_E units of high-skilled labour.[16] Once it has paid this entry cost, it receives a monopoly for the production of one intermediate i with idiosyncratic productivity $A(i)$, drawn from an exogenous cumulative distribution function G. The exogenous productivity distribution G is a Pareto distribution with minimum value 1 and shape parameter $k > \varepsilon - 1$, so that $G(A) = 1 - A^{-k}$. This distributional assumption is empirically realistic (see Chaney (2008), Melitz and Redding (2014) and Geerolf (2017)) and has convenient analytical properties which improve the model's tractability.

Upon learning its productivity draw, the firm decides whether to exit the market or to produce. In the latter case, it needs to choose its technology among three alternatives, ranging from a basic technology to two advanced ones. Advanced technologies increase firm productivity, but also have adoption costs.

The basic technology only uses low-skilled labour and allows the firm to produce with the production function $y(i) = A(i)\, l(i)$, where $l(i)$ stands for the units of low-skilled labour hired for production. It also entails a fixed cost of production of f units of low-skilled labour.

[15] Empirical evidence suggests that high-skilled workers are more mobile than low-skilled ones (Wozniak, 2010). Historically, Southern Europe had high emigration rates for low-skilled workers. However, the DIOC database described in the previous section shows that low-skill emigration from Southern Europe to the North increased by just 24% between 2000 and 2010, while high-skill emigration increased by 134%. We therefore focus on high-skilled emigration in our baseline analysis, but briefly analyse low-skilled emigration in Section 4 (see Footnote 36).

[16] Assuming that entry requires high-skilled labour reflects the fact that firm creation generally involves some high-skilled services (financing, administrative registration etc.). However, this assumption is not crucial for our main results, which would be unchanged if entry required low-skilled labour.

Alternatively, the firm can decide to use management, the first advanced technology. This has a fixed adoption cost of f_M units of high-skilled labour (on top of the fixed cost of production), and allows the firm to hire high-skilled managers which supervise production and increase its efficiency. We assume that firms need to hire $1/\eta$ units of high-skilled labour for every unit of low-skilled production labour, and that this increases their productivity by a factor $\exp(\alpha_0 + \alpha_1\xi)$. ξ is a parameter measuring the efficiency of management practices, while α_0 and α_1 are two positive parameters which determine the elasticity of firm productivity with respect to management efficiency. Throughout our analysis, we assume that the only difference between Northern and Southern countries is that Northern countries have more efficient management practices, i.e., $\xi^N > \xi^S$. Therefore, management adoption raises firm productivity in both regions, but more so in the North than in the South.

Finally, firms can also adopt IT, the second advanced technology. IT has a fixed adoption cost of f_{IT} units of high-skilled labour and raises firm productivity by a factor $\mathbb{1}_M \exp(\alpha_2\varphi + \alpha_3\xi\varphi)$, where $\mathbb{1}_M$ equals 1 if the firm uses management and 0 otherwise. The parameter φ represents the current state of IT technology, while the parameters α_2 and α_3 determine how IT affects firm productivity. Note that IT does not improve productivity in firms without management, and that an IT-adopting firm gets a higher productivity increase in a region with more efficient management practices (i.e., the production function is log-supermodular in the parameters ξ and φ). These two crucial assumptions capture the complementarities between IT and management documented in Section 2.2. Summarizing, the production function is

$$y(i) = \begin{cases} A(i)\, l(i) & \text{with the basic technology} \\ A(i) \exp(\alpha_0 + \alpha_1\xi) \min(\eta m(i), l(i)) & \text{with management and without IT} \\ A(i) \exp(\alpha_0 + \alpha_1\xi + \alpha_2\varphi + \alpha_3\xi\varphi) \min(\eta m(i), l(i)) & \text{with management and IT} \end{cases}, \tag{3}$$

where $m(i)$ stands for the units of high-skilled managerial labour employed by firm i and where we have already used the fact that no firm ever adopts IT without adopting management.

In our model, countries do not trade, but only interact through migration. For simplicity, we assume that there are only a discrete number of Southern countries, so that the South is arbitrarily small with respect to the North. Thus, Southern emigration does not affect Northern wages, which is plausible for our application, as emigration from Southern Europe was arguably too small to significantly affect wages in other OECD countries. This completes the model's assumptions, and we can now solve for its equilibrium.

3.2 Equilibrium conditions

To solve for the equilibrium, we conjecture that high-skilled and low-skilled wages are both higher in the North than in the South. This implies that Northern workers do not emigrate, and we can solve for the Northern equilibrium by disregarding migration completely. Then, we use Northern wages as parameters to solve for the Southern equilibrium, and verify that wages are indeed lower in the South.

3.2.1 Equilibrium conditions for Northern countries

Worker decisions In every Northern country, the income of worker j is given by w_L if she supplies low-skilled labour, and $j^{\nu_1} w_H$ if she supplies high-skilled labour, where w_H and w_L denote the wage rates for one unit of high and low-skilled labour. Thus, a low-skilled worker earns an entire low-skilled wage rate, while a high-skilled worker earns just a fraction of the high-skilled one, as she spends some of her labour endowment in education. This implies that in equilibrium, there is a skill premium: w_H must exceed w_L to incentivise some workers to become high-skilled.

It is easy to show that there exists a cut-off type j^* such that all workers with types between 0 and j^* become low-skilled and all workers with types between j^* and 1 become high-skilled. The cut-off is defined by

$$j^* = \left(\frac{w_L}{w_H}\right)^{\frac{1}{\nu_1}} . \tag{4}$$

Thus, the supply of high and low-skilled labour is

$$L = j^* = \left(\frac{w_L}{w_H}\right)^{\frac{1}{\nu_1}} \quad \text{and} \quad H = \int_{j^*}^{1} j^{\nu_1} dj = \frac{1}{1+\nu_1}\left(1 - \left(\frac{w_L}{w_H}\right)^{\frac{1+\nu_1}{\nu_1}}\right), \tag{5}$$

and we can express the relative supply of high-skilled labour as a simple increasing function of the skill premium $\frac{w_H}{w_L}$:

$$\frac{H}{L} = \frac{1}{1+\nu_1}\left(\frac{w_H}{w_L}\right)^{\frac{1}{\nu_1}}\left(1-\left(\frac{w_H}{w_L}\right)^{-\frac{\nu_1+1}{\nu_1}}\right). \tag{6}$$

Price setting and profits Cost minimization by final good producers implies that demand for any intermediate variety i is given by

$$y\left(i\right) = p\left(i\right)^{-\varepsilon}Y, \tag{7}$$

where we have normalized the price of the final good to 1 in each country.[17] Then, standard arguments show that each intermediate firm optimally chooses to set a price which is a mark-up $\frac{\varepsilon}{\varepsilon-1}$ over its marginal cost. The marginal cost of a firm using the basic technology is $\frac{w_L}{A}$.[18] Firms with management hire $1/\eta$ units of high-skilled management labour for every unit of production labour. Thus, their marginal cost of production is $\frac{w_L+\frac{w_H}{\eta}}{A\exp(\alpha_0+\alpha_1\xi)}$ if they do not adopt IT, and $\frac{w_L+\frac{w_H}{\eta}}{A\exp(\alpha_0+\alpha_1\xi+\alpha_2\varphi+\alpha_3\xi\varphi)}$ if they do. Combining price choices with the demand function in Equation (7), the profits of a firm that paid the entry cost and learned its productivity are therefore

$$\pi\left(A\right) = \begin{cases} \left(\frac{A}{w_L}\right)^{\varepsilon-1}B - fw_L & \text{with the basic technology} \\ \widetilde{\xi}\left(\frac{A}{w_L}\right)^{\varepsilon-1}B - fw_L - f_M w_H & \text{with management and without IT} \\ \widetilde{\varphi}\left(\frac{A}{w_L}\right)^{\varepsilon-1}B - fw_L - \left(f_M+f_{IT}\right)w_H & \text{with management and IT} \end{cases}, \tag{8}$$

where $B \equiv \frac{1}{\varepsilon-1}\left(\frac{\varepsilon}{\varepsilon-1}\right)^{-\varepsilon}Y$, $\widetilde{\xi} \equiv \left(\frac{\exp(\alpha_0+\alpha_1\xi)}{1+\frac{w_H}{\eta w_L}}\right)^{\varepsilon-1}$ and $\widetilde{\varphi} \equiv \left(\frac{\exp(\alpha_0+\alpha_1\xi+\alpha_2\varphi+\alpha_3\xi\varphi)}{1+\frac{w_H}{\eta w_L}}\right)^{\varepsilon-1}$.

Production and technology adoption Upon learning their idiosyncratic productivity draw A, firms must decide whether to exit or to produce with one of the three available technologies. While the profits from exit are 0 (abstracting from the sunk entry cost), the profits from the other options are given by Equation (8). Production, management and IT adoption all increase firms' variable profits, but have a fixed cost. Therefore, low-productivity firms, which have lower variable profits, are less likely to produce and to adopt technology than high-productivity firms. It is easy to show that firms sort according to their idiosyncratic productivity, so that their choices can be

[17] Note that we can normalize price levels independently in every country because there is no trade.
[18] For simplicity, we drop the firm index i from now on.

summarized by three cut-offs holding $1 \leq A^* \leq A_M^* \leq A_{IT}^*$. Firms with draws lower than A^* exit the market, firms with draws between A^* and A_M^* produce with the basic technology, firms with draws between A_M^* and A_{IT}^* produce with management, but without IT, and firms with draws higher than A_{IT}^* produce with both management and IT. For simplicity, we impose parameter restrictions which ensure $1 < A^* < A_M^*$, that is, that there are always some firms which do not produce, and some firms which produce without management.[19] Then, the exit cut-off is

$$A^* = w_L \left(\frac{f w_L}{B}\right)^{\frac{1}{\varepsilon-1}}. \tag{9}$$

For management and IT cut-offs, we need to distinguish two cases. When $\left(\widetilde{\varphi} - \widetilde{\xi}\right) f_M < \left(\widetilde{\xi} - 1\right) f_{IT}$,

$$A_M^* = w_L \left(\frac{f_M w_H}{\left(\widetilde{\xi} - 1\right) B}\right)^{\frac{1}{\varepsilon-1}} \quad \text{and} \quad A_{IT}^* = w_L \left(\frac{f_{IT} w_H}{\left(\widetilde{\varphi} - \widetilde{\xi}\right) B}\right)^{\frac{1}{\varepsilon-1}}. \tag{10}$$

Otherwise, we have

$$A_M^* = A_{IT}^* = w_L \left(\frac{(f_M + f_{IT})\, w_H}{(\widetilde{\varphi} - 1)\, B}\right)^{\frac{1}{\varepsilon-1}}. \tag{11}$$

Intuitively, if IT leads to a large productivity increase and/or its fixed cost is low, the second case applies and all firms with management also adopt IT. These cut-offs pin down the shares of producing firms using management and IT. Recalling that the probability that a producing firm has an idiosyncratic productivity draw higher than A is $\frac{1-G(A)}{1-G(A^*)} = \left(\frac{A^*}{A}\right)^k$, it follows that the share s_M of firms which use management and the share s_{IT} of firms which use IT are given by

$$s_M = \left(\frac{f\left(\widetilde{\xi} - 1\right)}{\frac{w_H}{w_L} f_M}\right)^{\frac{k}{\varepsilon-1}} \text{ and } s_{IT} = \left(\frac{f\left(\widetilde{\varphi} - \widetilde{\xi}\right)}{\frac{w_H}{w_L} f_{IT}}\right)^{\frac{k}{\varepsilon-1}}. \tag{12}$$

when there are some firms with management which do not use IT, and otherwise, by

$$s_M = s_{IT} = \left(\frac{(\widetilde{\varphi} - 1)\, f}{\frac{w_H}{w_L}\,(f_M + f_{IT})}\right)^{\frac{k}{\varepsilon-1}}. \tag{13}$$

These shares depend in an intuitive way on parameter values and on the skill premium. In particular,

[19] This configuration is empirically realistic: in the data, some firms exit shortly after their entry, and some firms produce without management. In the main text, we furthermore focus on equilibria in which A_M^* is finite (that is, in which at least some firms adopt management). All derivations and parameter conditions can be found in Appendix B.

all else equal, a higher skill premium depresses management and IT adoption, as firms producing with these advanced technologies need to employ more high-skilled labour than firms producing with the basic technology.

Free entry In equilibrium, the entry cost must be equal to the expected profits from firm creation. Using our previous results, this condition implies that

$$\begin{aligned} f_E w_H = & \int_{A^*}^{A_M^*} \left(\left(\frac{A}{w_L} \right)^{\varepsilon-1} B - f w_L \right) dG(A) + \int_{A_M^*}^{A_{IT}^*} \left(\widetilde{\xi} \left(\frac{A}{w_L} \right)^{\varepsilon-1} B - f w_L - f_M w_H \right) dG(A) \\ & + \int_{A_{IT}^*}^{+\infty} \left(\widetilde{\varphi} \left(\frac{A}{w_L} \right)^{\varepsilon-1} B - f w_L - (f_M + f_{IT}) w_H \right) dG(A). \end{aligned} \tag{14}$$

Combining this equation with the definition of the productivity cut-offs and using the properties of the Pareto distribution, we get

$$A^* = \left(\frac{(\varepsilon - 1) \left(f + \frac{w_H}{w_L} (s_M f_M + s_{IT} f_{IT}) \right)}{(k - (\varepsilon - 1)) \frac{w_H}{w_L} f_E} \right)^{\frac{1}{k}}. \tag{15}$$

Equation (15) holds both when some firms with management do not use IT (then, s_M and s_{IT} are given by Equation (12)) and when all firms with management also use IT (then, s_M and s_{IT} are given by Equation (13)). It defines the exit cut-off as a function of parameter values and of the skill premium. To determine the latter, we need to consider the labour market clearing conditions.

Labour market clearing and wages High-skilled labour demand can be determined by aggregating over firms' demands for managerial labour and the fixed costs of entry, management and IT. Likewise, low-skilled labour demand is the sum of the aggregate demands for production labour and for the fixed cost of production. We derive both demand functions in Appendix B and show that they define the relative demand for high-skilled labour as a decreasing function of the skill premium, given by

$$\frac{H}{L} = \frac{\frac{k(\varepsilon-1)f}{\eta + \frac{w_H}{w_L}} \left(\widetilde{\xi} s_M^{1-\frac{\varepsilon-1}{k}} + \left(\widetilde{\varphi} - \widetilde{\xi} \right) s_{IT}^{1-\frac{\varepsilon-1}{k}} \right) + \left((\varepsilon - 1) \frac{w_L}{w_H} f + k (s_M f_M + s_{IT} f_{IT}) \right)}{(k - (\varepsilon - 1)) f + k (\varepsilon - 1) f \left(1 + \left(\frac{\widetilde{\xi}}{1 + \frac{w_H}{\eta w_L}} - 1 \right) s_M^{1-\frac{\varepsilon-1}{k}} + \left(\frac{\widetilde{\varphi} - \widetilde{\xi}}{1 + \frac{w_H}{\eta w_L}} \right) s_{IT}^{1-\frac{\varepsilon-1}{k}} \right)}. \tag{16}$$

By equating the relative demand of high-skilled labour with the relative supply, given by Equation (6), we obtain a non-linear equation for the skill premium, which can be solved numerically. Given the skill premium, it is easy to solve for the other endogenous variables. Equation (5) pins down the masses of high and low-skilled labour, Equations (12) or (13) the shares of firms using management and IT, and Equation (15) the value of the exit cut-off. Furthermore, note that free entry implies that all aggregate profits are paid as wages to workers. Thus, the national income identity implies $Y = w_L L + w_H H$. Combining this with the definition of the auxiliary variable B and the exit cut-off defined by Equation (9), we get

$$w_L = \frac{\varepsilon - 1}{\varepsilon} A^* \left(\frac{L + \frac{w_H}{w_L} H}{\varepsilon f} \right)^{\frac{1}{\varepsilon - 1}}, \tag{17}$$

which pins down w_L. From this, we can then directly deduce w_H and output Y. Finally, Appendix B shows how we can use the labour market clearing conditions to also determine the mass of producing firms M.

Having completely characterized the equilibrium in the North, we can now turn to the South. Our analysis will be largely symmetrical, except for the fact that we now need to consider migration.

3.2.2 Equilibrium conditions for Southern countries

Worker decisions The income of a Southern worker of type j who decides to stay at home is given by w_L^S if she supplies low-skilled labour and by $j^{\nu_1} w_H^S$ if she supplies high-skilled labour. A high-skilled worker which decides to emigrate to the North earns instead $j^{\nu_1+\nu_2} w_H^N$. Recall that because the South is arbitrarily small, Northern wages do not depend on the Southern equilibrium and can be considered as parameters in this section.

As Northern wages are higher than Southern ones, some workers are better off emigrating. As a consequence, Southern workers sort into three groups: workers with types below j^{S*} supply low-skilled labour at home, workers between j^{S*} and j_E^{S*} supply high-skilled labour at home, and workers with types larger than j_E^{S*} emigrate and supply high-skilled labour in the North. Cut-offs are given by

$$j^{S*} = \left(\frac{w_L^S}{w_H^S} \right)^{\frac{1}{\nu_1}} \text{ and } j_E^{S*} = \left(\frac{w_H^S}{w_H^N} \right)^{\frac{1}{\nu_2}}. \tag{18}$$

Accordingly, the supply of high-skilled and low-skilled labour in a Southern country is given by

$$L^S = \left(\frac{w_L^S}{w_H^S}\right)^{\frac{1}{\nu_1}} \quad \text{and} \quad H^S = \int_{j^{S*}}^{j_E^{S*}} j^{\nu_1} dj = \frac{1}{1+\nu_1}\left(\left(\frac{w_H^S}{w_H^N}\right)^{\frac{1+\nu_1}{\nu_2}} - \left(\frac{w_L^S}{w_H^S}\right)^{\frac{1+\nu_1}{\nu_1}}\right). \tag{19}$$

Thus, the relative supply of high-skilled labour is

$$\frac{H^S}{L^S} = \frac{1}{1+\nu_1}\left(\frac{w_H^S}{w_L^S}\right)^{\frac{1}{\nu_1}}\left(\left(\frac{w_H^S}{w_H^N}\right)^{\frac{1+\nu_1}{\nu_2}} - \left(\frac{w_L^S}{w_H^S}\right)^{\frac{1+\nu_1}{\nu_1}}\right). \tag{20}$$

Note that the relative supply of high-skilled labour now does not only depend on the skill premium, but also on the ratio of Southern to Northern high-skilled wages. When this ratio decreases, emigration increases and the Southern relative supply of high-skilled labour shifts downwards.

Firm decisions and equilibrium Firm decisions in the South can be determined exactly as in the North. In particular, Equation (16) still defines the relative demand for high-skilled labour. However, the condition that relative supply and demand of high-skilled labour must be equal is no longer sufficient to pin down the skill premium, because relative supply now does not only depend on the skill premium, but also on the ratio of Southern to Northern high-skilled wages. Therefore, we need an additional equilibrium condition. This additional condition is given by Equation (17), which also holds for Southern countries. Together with the relative labour market clearing condition, it defines a system of two equations in two unknowns (the Southern wages w_L^S and w_H^S) that can be solved numerically.

Knowing Southern wages, we can deduce the equilibrium values of the other endogenous variables: domestic supply of high and low-skilled labour are given by Equation (19), national income is still given by $Y^S = w_L^S L^S + w_H^S H^S$, and the mass of firms M^S can be determined in the same way as for the Northern countries.

This concludes the characterization of our model's solution. In the next section, we explain how we use it to analyse the IT Revolution, and how the latter generates divergence between the North and the South. This illustrates the channels at work and paves the way for a quantitative analysis of divergence in Section 4.

3.3 Results: IT, management efficiency and divergence

3.3.1 The North and the South before and after the IT Revolution

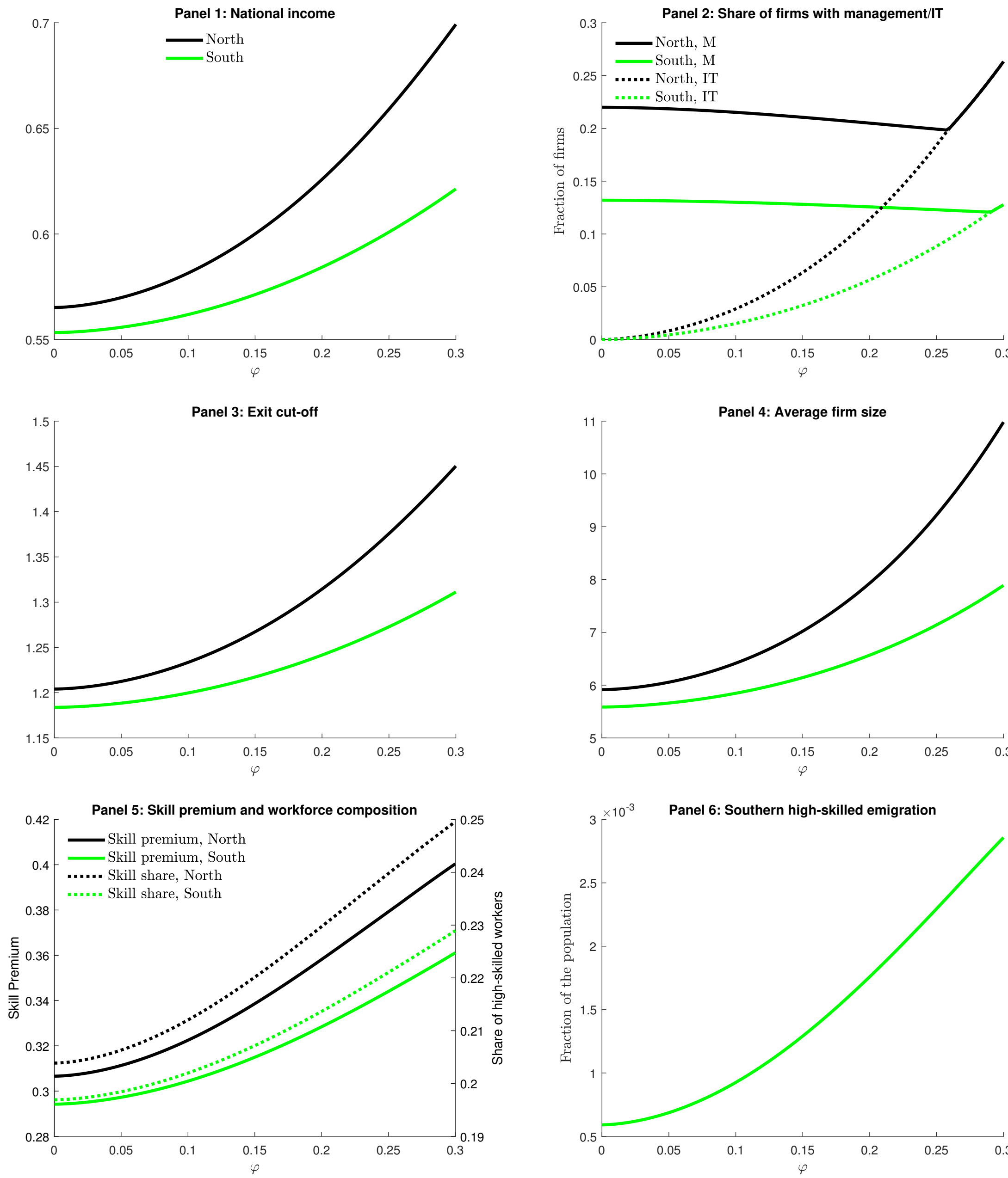
To analyse the impact of the IT Revolution, we compare our model's equilibrium with $\varphi = 0$, which represents the situation "before" the IT Revolution, when IT adoption was not possible, to its equilibrium with $\varphi > 0$, which represents the situation "after" the IT Revolution. Figure 4 provides a graphical illustration of our main results, by plotting the equilibrium values of several key variables for different values of φ.[20] Even though our model is static, one could interpret the figure as showing a succession of steady states over time as the IT Revolution progresses and IT becomes more and more productive. The parameter values used for this figure are the same as in the baseline calibration of our quantitative analysis (see Section 4).

Even before the IT Revolution, there are several differences between the North and the South. As management is less efficient in the South, management adoption is lower as well, as shown in Panel 2. Furthermore, the Southern firms which adopt management do not increase their productivity as much as their Northern counterparts. This reduces the competitive pressure on low-productivity firms and thus the cut-off level of productivity needed to stay in the market (see Panel 3). As a result, Southern countries have on average smaller firms than Northern ones (see Panel 4), lower aggregate productivity and lower national income (see Panel 1). Moreover, lower management adoption rates depress the demand for high-skilled labour, lowering both the skill premium and the high-skilled share of the workforce, as shown in Panel 5. Finally, as Northern wages are higher than Southern ones, some Southern high-skilled workers emigrate. This shifts the Southern high-skilled labour supply downwards, which all else equal increases the skill premium (reflecting the fact that the marginal high-skilled worker now faces a higher education cost). Thus, assuming only one simple difference between the North and the South, our model can reproduce a large number of stylized facts: compared with other OECD members, Southern Europe has smaller firms, less management, lower productivity, less high-skilled workers and more high-skilled emigration.

Figure 4 also shows that the qualitative effects of the IT Revolution are the same in both regions.

[20] As our model does not admit an analytical solution, we cannot formally prove all numerical results. In Appendix B, we however provide some analytical proofs for a simplified version of our model, without migration and worker heterogeneity.

Figure 4: The impact of the IT Revolution



Note: The parameter values used to draw these figures correspond to the baseline calibration (see Section 4). The North corresponds to our calibration for Germany, the South to our calibration for Italy.

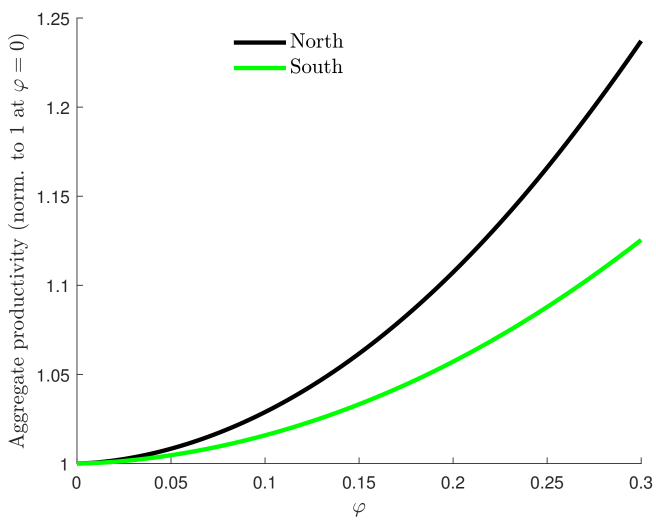
More advanced IT technology obviously raises IT adoption (see Panel 2) and national income (see Panel 1). It also enhances selection: as high-productivity firms adopt IT and increase their market share, some low-productivity firms exit the market and average firm size increases (see Panels 3 and 4). Furthermore, the IT Revolution raises the demand for high-skilled labour (which is needed for IT adoption costs) and therefore jointly raises the skill premium and the high-skilled share of the workforce.[21]

This analysis shows that the IT Revolution raises incomes both in the North and in the South. However, as Figure 4 already indicates, it increases Northern incomes more than Southern ones. We turn to this point in the next section.

3.3.2 Drivers of divergence

Figure 5 plots output per worker in a Northern and in a Southern country as a function of the state of IT technology φ. Both series are normalized to 1 in the equilibrium before the IT Revolution. Output per worker is our model's equivalent to aggregate productivity in the data, and from now on, we refer to it simply as productivity. The figure clearly shows that the IT Revolution increases productivity differences between the North and South, and that this effect is increasing in φ. This divergence arises through three channels.

Figure 5: The IT Revolution and productivity divergence in the model



Note: See Figure 4.

[21] Management adoption by firms which do not use IT is subject to opposing forces. On the one hand, higher skilled wages and lower market shares due to stronger competition from IT-adopting firms reduce the incentives of firms to use management without IT. On the other hand, higher selection lowers the mass of low-productivity firms producing with the basic technology, and therefore mechanically increases the share of producing firms which use management. Depending on which effect is stronger, an increase in φ lowers or increases the share of firms with management. However, once φ passes a certain threshold, further increases unambiguously raise management adoption, as it is a prerequisite for IT adoption. Furthermore, the IT Revolution always raises the fraction of workers employed by firms that use management.

First, the management-IT complementarity means that Southern firms get a smaller productivity gain than Northern ones when adopting IT. Obviously, this directly implies that Southern aggregate productivity gains are also lower. This is compounded by the fact that Southern IT adoption rates are lower (consistent with the evidence shown in Table 1): all else equal, Southern firms have less incentives to adopt IT, and because of inefficient management, they are on average smaller and thus less willing to pay the fixed cost of IT adoption. When IT productivity becomes arbitrarily high, all firms use IT and differences in adoption rates disappear. However, our log-supermodular specification of production technology implies that differences in productivity gains between Northern and Southern firms increase in IT productivity, so that divergence monotonically increases with the strength of the IT Revolution.

Second, the IT Revolution makes the South's management disadvantage more salient through a composition effect. Southern firms are as productive as Northern ones for the basic technology, but less productive for management. Thus, as the IT Revolution increases the employment share of firms using management, it fosters divergence. Note that this channel does not directly depend on the management-IT complementarity, but is essentially due to the size-biased nature of IT. Indeed, management is only adopted by large firms. Thus, any other technological change which is only adopted by large firms increases their employment share and therefore triggers divergence.

Third, the IT Revolution increases Northern wages more than Southern ones, and therefore endogenously increases Southern high-skilled emigration rates (see Panel 6 of Figure 4). This lowers Southern productivity, as it increases the education cost faced by the marginal high-skilled worker. It also, all else equal, increases the skill premium, and therefore further depresses IT adoption.

Note that technological change does not always leads to divergence between countries with different levels of management efficiency. For instance, in our model, Hicks-neutral technological change without fixed costs (modelled as an upward shift in the exogenous productivity distribution) would have an exactly symmetrical effect across all countries. The IT Revolution only leads to divergence because it is both management- and size-biased.

Thus, our analysis suggests a simple narrative for Southern Europe's growth performance in recent economic history. In the decades before the 1990s, technological change was neither size- nor management-biased, and Southern Europe grew at least as fast as other OECD countries.[22] In

[22] In fact, Southern European TFP growth was generally higher than the OECD average before the 1990s. One

the middle of the 1990s, however, the nature of technological change changed. The new frontier technology, IT, had a strong complementarity with efficient management practices and therefore stimulated TFP growth in Southern Europe less than in other countries, made its management problems more salient, and incentivized more and more highly educated workers to emigrate. We now proceed to a quantitative analysis of these mechanisms.

4 Quantitative results

In this section, we assess the importance of the IT Revolution for the divergence between three Southern European countries (Italy, Spain and Portugal) and Germany, the largest economy in Northern Europe, between 1995 and 2008.[23] To do so, we assume that Germany is representative for the North in our model, and consider successively each of the three Southern European countries as representative for the South.[24] We then calibrate the model using micro- and macro-level evidence on the productivity effects of management and IT adoption, and a series of moments for Germany in 2008. Throughout, the only difference between the parametrization for Germany and for the three Southern European countries is the value of the management efficiency parameter ξ. As before, we assess the IT Revolution by comparing our model's equilibrium without IT (where $\varphi = 0$) to its equilibrium with IT (where $\varphi = \varphi_{IT}$, which is a positive number to be calibrated).

4.1 Calibration

4.1.1 Externally calibrated parameters

The firm-level productivity gains from management and IT adoption depend on six parameters: the management efficiency and IT parameters ξ and φ_{IT}, and the elasticities which determine how

interpretation of this fact that is consistent with our narrative is that during that period, the type of technological progress most relevant for Southern Europe was biased towards basic technologies and unskilled labour. Indeed, during their catch-up phase, Southern European countries experienced a massive shift from agriculture to manufacturing and imported technologies that were already widespread in frontier economies, and that did not rely so heavily on efficient management practices.

[23]We stop in 2008, as the subsequent financial crisis may have amplified divergence for reasons not captured in our model. However, we show below that a calibration for the whole period 1995-2015 leads to very similar results.

[24]Alternatively, we could allow for heterogeneity among Southern countries in our model, and consider all three countries jointly. This would not change results, as Southern countries do not interact (Southern emigrants move to the North, not to other Southern countries). Considering Germany as representative for the North is a conservative choice. As shown in Figure 3, it had lower productivity growth than the United States and the United Kingdom, and thus also presumably lower wage growth, reducing the pull factor of its wage increases for Southern emigrants.

they map into productivity (α_0 to α_3). With one important exception, we set all these parameter values externally, relying on micro-level evidence.

In order to calibrate management efficiency ξ, we rely on the WMS management scores described in Section 2, and set ξ equal to the average standardized management score for every country considered. This average score is 0.467 for Germany, 0.110 for Italy, -0.124 for Portugal and -0.232 for Spain. Calibrating the contribution of IT is trickier. The parameter φ_{IT} captures the total productivity impact of the IT Revolution. As we discussed in Section 2, IT consists of a large number of heterogeneous technologies. Therefore, it would be hard to rely on microeconomic evidence for one specific technology (such as computers, ERP, SCM or the internet) to pin down φ_{IT}. Instead, we will calibrate this parameter internally, by targeting an aggregate growth rate which is consistent with the best estimates for the contribution of IT to aggregate productivity growth in the frontier economies between 1995 and 2008.

In order to calibrate the elasticity parameters α_0-α_3, we note that in our model output per production worker of a management-adopting firm i is given by

$$\ln\left(\frac{y_i}{l_i}\right) = \alpha_0 + \alpha_1\xi + \mathbb{1}_{IT,i}\left(\alpha_2\varphi_{IT} + \alpha_3\xi\varphi_{IT}\right) + \ln\left(A_i\right), \tag{21}$$

where $\mathbb{1}_{IT,i}$ is an indicator function that equals 1 if firm i adopts IT, and 0 if it does not. In order to take Equation (21) to the data, we make three additional assumptions. First, while in our model we assumed for simplicity that all firms from a given country have the same management efficiency, we allow management efficiency to be firm-specific in the data, and measure it, as above, with the firm's standardized WMS score. Second, while IT adoption is a binary decision in our model, we allow it to be continuous in the data, and proxy firm i's degree of IT adoption by the variables introduced in Section 2, that is, by the fraction of a firm's plants using a certain software. Third, in the absence of firm level prices, we make the widely used assumption that output per worker can be approximated with sales per worker. Thus, our measurement equation becomes

$$\ln\left(\frac{\text{Sales}_i}{l_i}\right) = \alpha_0 + \alpha_1 WMS_i + \alpha_2\varphi_{IT} IT_i + \alpha_3\varphi_{IT} WMS_i \cdot IT_i + \ln\left(A_i\right). \tag{22}$$

Equation (22) corresponds to our specification in Table 2 of the empirical section. Throughout, we focus on Column [1] of the table, which contains the results for the most general measure of IT adoption.[25] These results suggest $\alpha_1 \approx 0.05$. That is, abstracting from IT, a unit increase in the standardized management score increases firm productivity by around 5%. This estimate is in the range of the empirical evidence summarized in Bloom et al. (2016), who, based on experimental and cross-sectional evidence, conclude that a unit increase in the standardized management score increases firm productivity by around 10%. Given that this estimate is based on a large body of evidence, we use $\alpha_1 = 0.1$ in our baseline calibration, but we show in Section 4.3 that results are similar when setting $\alpha_1 = 0.05$.

Furthermore, our estimates suggest $\alpha_2 \varphi_{IT} \approx 0.085$ and $\alpha_3 \varphi_{IT} \approx 0.091$. As the scale of φ_{IT} is indeterminate in our model,[26] we normalize $\alpha_2 = 1$ and then set $\alpha_3 = {}^{0.091}/_{0.085} \approx 1.071$. This estimate is remarkably similar to the one of Bloom et al. (2012), who estimate a close equivalent of Equation (22) using hardware adoption (computers per worker) as a measure of IT and find $\alpha_3 \approx 1.014$.[27] Thus, the degree of management-IT complementarity implied by our calibration of α_3 seems to apply to a broad range of IT technologies, which is reassuring.

Finally, we need to calibrate the parameter α_0. For this, we cannot rely on the estimates in Table 2, as the constant in our regression confounds α_0 and common components in firm productivity. Instead, we note that in our model, a firm which adopts management increases its productivity by $\alpha_0 + \alpha_1 \xi$ log points. Thus, if we had an estimate for the increase in productivity induced by management adoption, we could pin down α_0. To get this number, we rely on a dataset constructed by Guiso et al. (2015), who ran a close equivalent of the WMS on a sample of small Italian firms without formal management structures (see Appendix A for a full description of the dataset). The average management score of these firms is -1.110. Assuming that management adoption brings them to the average management score of management-adopting firms in Italy (0.110), and using the Bloom et al. (2016) elasticity of productivity to better management, management adoption increases their productivity by $(0.11 - (-1.11)) \cdot 0.1 = 0.122$ log points, implying $\alpha_0 = 0.111$. We will consider extensive robustness checks on all of these parameter values in Section 4.3.

We calibrate two more parameters externally. Following a common practice in the literature, we

[25] Note that the WMS only targets medium-size firms (between 50 and 5.000 employees) that are expected to have a formal management structure. This is consistent with the assumption that we estimate Equation (22) on a sample of management-adopting firms.

[26] Indeed, we can always rewrite firm-level productivity increase after IT adoption as $\exp\left((\alpha_2 \varphi_{IT}) + \frac{\alpha_3}{\alpha_2} \xi (\alpha_2 \varphi_{IT})\right)$.

[27] These results are stated in Column 3 of Table 6 (P.195) of Bloom et al. (2012). The coefficient on computers per worker is 0.143, while the coefficient on the interaction of computers per worker and management score is 0.145.

set the elasticity of substitution between intermediates to 3 (Hsieh and Klenow, 2009, Jones, 2011). The tail of the firm size distribution in our model is Pareto with shape parameter $\frac{k}{\varepsilon-1}$. To match the shape of size distributions in the data, we set k such that $\frac{k}{\varepsilon-1} = 1.65$, following Arkolakis (2010). His estimate, which uses French data, is close to the median value used in the literature on quantitative Melitz models (for instance, Chaney (2008) uses 2, while Melitz and Redding (2015) use 1.42). We consider robustness tests for both the elasticity of substitution and the shape parameter of the size distribution in Section 4.3.

Table 4: Externally calibrated parameters

Parameter	Value	Description	Parameter	Value	Description
ξ^{DEU}	0.467	Management efficiency, Germany	α_1	0.1	Elasticity of prod. w.r.t. to ξ
ξ^{ITA}	0.110	Management efficiency, Italy	α_2	1	Elasticity of prod. w.r.t. to φ
ξ^{PRT}	−0.124	Management efficiency, Portugal	α_3	1.071	Elasticity of prod. w.r.t. to $\xi\varphi$
ξ^{ESP}	−0.232	Management efficiency, Spain	ε	3	Elasticity of substitution
α_0	0.111	Direct effect of mgmt	k	3.3	Pareto shape parameter

4.1.2 Internally calibrated parameters

There are eight more parameters to calibrate: the state of IT technology φ_{IT}, the fixed costs of entry f_E, of production f, of management adoption f_M, of IT adoption f_{IT}, the span of control of managers η and the parameters determining the costs of skill acquisition υ_1 and migration υ_2. We set these parameter values by choosing the parameter vector $\boldsymbol{\theta} = (\varphi_{IT}, f_E, f, f_M, f_{IT}, \eta, \nu_1, \nu_2)$ that solves

$$\min_{\boldsymbol{\theta}} \sum_{s=1}^{8} \left(\frac{\text{Moment}_s\,(\text{Data}) - \text{Moment}_s\,(\boldsymbol{\theta}, \text{Model})}{\text{Moment}_s\,(\text{Data})} \right)^2, \tag{23}$$

All moments refer to the model's equilibrium for Germany after the IT Revolution. Most importantly, we target German productivity growth induced by the IT Revolution. In our model, this corresponds to the increase in Germany's aggregate productivity between the equilibrium without IT and the equilibrium with IT. To pin down this growth rate, we rely on growth accounting evidence. For the United States, Byrne et al. (2013) find that IT accounted for 57% of all growth in real output per worker (net of non-IT capital deepening) in the nonfarm business sector between 1995 and 2008. At the same time, the OECD data discussed in the introduction indicates an overall US productivity (real output per hour worked, net of non-IT capital deepening) growth of 25.2%. Thus, assuming that the decomposition of Byrne et al. for the nonfarm business sector also applies to the overall economy, IT accounts for a 13.6% increase in US productivity between 1995 and 2008.[28] To the best of our knowledge, there are no comparable studies for Germany. We therefore use our model to discipline the German growth rate, by assuming that if Germany's management score were equal to the one of the US,[29] German productivity would also have grown by 13.6%. We consider robustness checks for this target in Section 4.3.

Second, we target the share of German employment in IT-using firms. As noted before, IT refers to a wide array of technologies. Thus, there is no single adoption rate: while nearly all firms have access to the internet, only a subset of firms use ERP or SCM software. For our main IT adoption measures discussed in Section 2, adopting firms represent approximately 40% (for CRM and SCM), 65% (for ERP) or more than 95% (for the internet) of total employment in Germany in 2014.[30] Thus, we target an employment share of 50% for 2008, but perform extensive robustness checks around this value. Together with the German growth rate, this moment disciplines the strength of the IT Revolution in the model, that is, the parameters φ_{IT} and f_{IT}.

Third, we target the share of German employment in management-using firms. As in the previous section, we identify firms which use management with firms having at least 50 employees. Using Eurostat's structural business statistics (SBS), we find that the employment share of firms with more than 50 employees was 57.9% in 2012, the first year in which a decomposition of employment by size classes is available. This moment disciplines the fixed cost of management adoption f_M.

Fourth, we target the average number of employees of German firms and firms' exit rate, using again the SBS. These show that in 2008, the average German firm had 8.0 employees. In our model, all exit occurs endogenously immediately after entry. Many studies (e.g., Bartelsman et al. (2005) for a set of OECD countries and Fackler et al. (2013) for Germany), show that exit hazard rates of

[28] According to Table 1 in Byrne et al. (2013), real GDP per worker in the US nonfarm business sector grew by 33.8 log points between 1995 and 2008. Netting out the contribution of non-IT capital (5.5 log points), a productivity growth rate of 28.3 log points remains. As the total contribution of IT to growth in real GDP per worker during these years was 16.1 log points, it follows that IT accounted for 57% ($^{16.1}/_{28.3}$) of all productivity growth. Assuming that the same percentage holds for the overall economy, and noting that the OECD data discussed in the introduction implies that US productivity has increased by 22.5 log points between 1995 and 2008 yields an overall IT contribution of 12.7 log points ($0.57 \cdot 22.5$), or 13.6%.

[29] The average management score of US firms is $\xi^{USA} = 0.612$.

[30] See Appendix A for further details on this and on the following data sources.

entering firms stabilize approximately five years after entry. The Eurostat SBS show that in 2009 (the first year in which this data is available), 40.2% of all German firms which entered in 2004 were still active, so we target an endogenous exit rate of 59.8%. Average employment and the exit rate jointly determine the fixed costs f_E and f.

Fifth, we target the share of high-skilled workers in the German workforce and the German skill premium, using the EU SILC database. Throughout, we define high-skilled workers in the data as workers with tertiary education. The data show that in 2015, 22.2% of the German population between 18 and 64 years had tertiary education, and that the average net annual income of these people was 35.8% higher than that of the rest of the population. The skill premium and the share of high-skilled workers jointly discipline the span of control of managers η and the education cost parameter ν_1.

Finally, German moments can of course not identify the migration cost parameter ν_2, as there is no German emigration in our model. Thus, we discipline this last parameter using the DIOC database introduced in Section 2.3. The data show that in 2010/2011, the net stock of high-skilled Southern emigrants amounted to 1.26% of their domestic high-skilled population, and we target this number.[31]

Table 5: Targeted moments

Moment	Country	Data	Model
IT-induced productivity growth	United States	13.6%	13.6%
IT-induced productivity growth	Germany	n.a.	11.1%
Employment in firms with IT	Germany	50.0%	50.0%
Employment in firms with management	Germany	57.9%	57.7%
Average firm size (employees)	Germany	8.0	8.0
Exit rate	Germany	59.8%	59.8%
Percentage of high-skilled workers	Germany	22.2%	23.0%
Skill premium	Germany	35.8%	35.9%
Emigration (perc. of high-skilled pop.)	South	1.26%	1.26%

[31] Precisely, to calibrate ν_2, we consider a hypothetical Southern country whose management score is the simple average of the scores of Italy, Portugal and Spain. Results do not change if we use a population-weighted average.

We solve the minimization problem defined by Equation (23) with a Differential Evolution algorithm. Table 5 shows that our model matches the targeted moments very closely (which is not surprising, given that the calibration is exactly identified). The model implies a German productivity growth of 11.1%, around 82% of the US value. Table 6 shows the implied parameter values.

Table 6: Internally calibrated parameters

Parameter	Value	Description	Parameter	Value	Description
f_E	0.557	Entry cost	φ_{IT}	0.203	State of IT technology
f	0.737	Fixed cost of production	η	100	Managers' span of control
f_M	0.474	Management adoption cost	ν_1	1.173	Education cost parameter
f_{IT}	2.220	IT adoption cost	ν_2	47.21	Emigration cost parameter

The fixed costs imply reasonable magnitudes for adoption costs: IT adoption and management costs jointly represent approximately 5.2% of German national income. The average high-skilled worker uses up around 13.3% of her labour endowment in education, and the average manager can supervise around 87 production workers.[32]

4.1.3 Model fit

To examine our model's fit, Table 7 compares its moments generated for Southern European countries after the IT Revolution to their (non-targeted) data equivalents in 2008, or in the closest year with available data. Even though our calibration used almost no information on Southern Europe, it roughly matches the Southern European shares of firms with management and exit rates. Average firm size and the share of high-skilled workers in the workforce are lower in Southern Europe than in Germany, even though the model somewhat overpredicts their level with respect to the data.[33] Finally, it turns out that in the data, skill premia are higher in Southern Europe than in Germany. This finding may be due to taxes. For our calibration, we have used data on net wages, as these are most relevant for workers making occupational choices. However, when looking at gross wages, which are more directly subject to market forces, it turns out that the skill premium in Italy is

[32]The average high-skilled worker supplies 0.867 units of labour, and every unit can supervise 100 production workers.

[33]Spain is an exception in this regard, with a very high share of the population having tertiary education.

substantially lower than in Germany, and the one in Spain is somewhat lower.[34]

Table 7: Non-targeted moments (Southern Europe, after the IT Revolution)

	Italy		Portugal		Spain	
	Data	Model	Data	Model	Data	Model
Emp. in firms with management	33%	46%	37%	37%	40%	32%
Average firm size (employees)	4.1	6.6	3.7	6.0	4.3	5.8
Exit rate	50%	51%	65%	46%	51%	44%
Share of high-skilled workers	14%	21%	13%	20%	29%	20%
Skill premium	52%	33%	110%	31%	50%	30%

Note: Data sources and definitions are the same as for Germany. See details in Appendix A.

Overall, this evidence suggests that management efficiency (the only difference between Southern Europe and Germany in our model) can explain a substantial part of several cross-country differences in the productive structure, even though it can of course not account for all the differences. We are now ready to consider our model's predictions for divergence.

4.2 Quantitative implications

Table 8 contains our model's main quantitative predictions. Column [1] shows some summary statistics for the equilibrium before the IT Revolution (where $\varphi = 0$). Germany's higher management efficiency already implies a 2.0% productivity gap with respect to Italy, a 3.1% gap with respect to Portugal, and a 3.6% gap with respect to Spain. The IT Revolution amplifies these differences, as its productivity impact is lower in Southern Europe. This can be seen in Column [2], showing the equilibrium after the IT Revolution (where $\varphi = \varphi_{IT}$): with respect to the equilibrium before the IT Revolution, aggregate productivity increases by 11.1% in Germany, but only by 5.9% in Italy, 3.4% in Portugal and 2.5% in Spain. Differences between Southern European countries reflect their management scores: Italy fares best because it has the highest score in Southern Europe, and Spain worst because it has the lowest one. Furthermore, divergence is stronger for high-skilled wages, as the skill premium rises more strongly in Germany than in Southern Europe.

[34] Data for gross wages from the OECD "Education and Training" database gives a gross skill premium of 59.4% for Germany (in 2014), 50.4% for Italy and 58.8% for Spain (in 2013).

Table 8: Quantitative results for the baseline calibration

	[1] Without IT				[2] With IT			
	DEU	ITA	PRT	ESP	DEU	ITA	PRT	ESP
Productivity rel. to Germany	1	0.980	0.969	0.964	1	0.934	0.902	0.890
Productivity growth					11.1%	5.9%	3.4%	2.5%
Share of actual divergence						35%	81%	47%
Low-skilled wage rel. to Germany	1	0.982	0.972	0.968	1	0.940	0.911	0.900
High-skilled wage rel. to Germany	1	0.972	0.958	0.952	1	0.919	0.878	0.863
Emp. in firms with management	49%	39%	32%	28%	58%	46%	37%	32%
Emp. in firms with IT	0%	0%	0%	0%	50%	36%	27%	23%
Skill premium	31%	29%	29%	28%	36%	33%	31%	30%
Share of high-skilled workers	20%	20%	19%	19%	23%	21%	20%	20%
Emigrants (% of high-skilled)	0%	0.3%	0.5%	0.6%	0%	0.8%	1.4%	1.6%
Emigrants (% of total population)	0%	0.06%	0.09%	0.10%	0%	0.18%	0.27%	0.31%

Note: Productivity in our model is measured as output per worker.

How much of the actually observed divergence between Southern Europe and Germany can be explained by the IT Revolution? To answer this question, we confront the divergence generated by our model to the one observed in the data. According to the OECD data discussed in the introduction (see Figure 1), the difference in aggregate productivity growth rates with respect to Germany was 14.9 percentage points for Italy, 18.4 percentage points for Spain, and 9.4 percentage points for Portugal. In our model, the corresponding numbers are 5.2, 7.7 and 8.6 percentage points. Thus, over the period 1995-2008, our model accounts for 35% ($^{5.2}/_{14.9}$) of Italy's , 47% ($^{8.6}/_{18.4}$) of Spain's and 81% ($^{7.7}/_{9.4}$) of Portugal's divergence with respect to Germany.

As discussed in Section 3, divergence is due to three channels: the direct effect of lower IT adoption and lower productivity gains from adopted IT, the increase in the employment share of firms with management, and high-skilled emigration. We can use the model to assess the relative strength of these channels. To do so, we start by shutting down the first channel, setting $\alpha_3 = 0$ and recalibrating the model to match the targets described in the previous section.[35] Now, Southern European and German firms experience the exact same productivity increase when adopting IT. However, the IT Revolution still triggers divergence, because it increases the employment share of firms with management and stimulates emigration. In this alternative calibration, differences in productivity growth are substantially lower, amounting to 0.6 percentage points for Italy, 1.1 percentage points for Portugal and 1.4 percentage points for Spain. Thus, lower productivity gains and lower IT adoption account for the largest part of divergence, while the remainder is due to composition changes and emigration. Among these latter channels, composition changes dominate. Indeed, emigration has only a small effect: when we set the migration cost parameter ν_2 to $+\infty$ in our baseline calibration, thus shutting down emigration, productivity growth only increases by 0.12 percentage points in Italy, 0.17 percentage points in Portugal, and 0.19 percentage points in Spain.[36] Thus, the most important driver of divergence is the fact that Southern European firms adopt less IT and benefit less from the IT they adopted. The increase in the aggregate importance of management triggered by the IT Revolution also makes a non-negligible contribution, while emigration of high-skilled workers, even though large in absolute terms (high-skilled emigration triples in all three Southern countries) has a relatively limited impact on divergence.

Finally, it is instructive to consider the differences between the aggregate and firm-level results. As shown in Table 8, Italy's aggregate growth rate in the baseline calibration represents around 53% of the German one. However, at the firm level, productivity differences are actually substantially smaller: an IT-adopting Italian firm increases its output per worker by 72% as much as a German firm.[37] This shows that inferring the aggregate consequences of the IT Revolution directly from reduced-form microeconometric regressions (such as the ones shown in Section 2) would be highly misleading. In the context of our model, this would miss the fact that Southern European IT adoption rates are lower, that the IT Revolution increases the aggregate importance of management,

[35] We need to recalibrate the model because otherwise, the implied growth rate for Germany would be much lower, and our results for the alternative parametrization would not be comparable to the baseline.

[36] In our model, emigration lowers aggregate productivity because it increases the education costs of the marginal high-skilled worker, but also because love for variety implies that aggregate productivity depends on population size (for empirical evidence on this, see Peters, 2017). To assess the relative strength of the two channels, we consider a counterfactual without high-skilled migration, but with exogenous low-skilled emigration, set equal to the emigrant shares in the population shown in Table 8, both before and after the IT Revolution. This low-skilled emigration lowers productivity growth by roughly half as much as the increase in high-skilled emigration did.

[37] For a firm that already uses management, output per worker increases by a factor $\exp\left(\alpha_2\varphi_{IT} + \alpha_3\xi\varphi_{IT}\right)$ when adopting IT. Thus, firm-level productivity differences are given by $\exp\left(\alpha_3\left(\xi^{ITA} - \xi^{DEU}\right)\varphi_{IT}\right)$.

and that it stimulates high-skilled emigration. All these margins combined imply that the aggregate divergence is almost twice as large as the firm-level one.

Overall, our model indicates that the IT Revolution substantially contributed to Southern Europe's divergence. In the next section, we discuss a number of robustness checks around our baseline calibration and perform some counterfactuals of policy interest.

4.3 Robustness checks and counterfactuals

4.3.1 Robustness checks

Table 9 reports a series of robustness checks. As noted before, we rely on US growth accounting data and on our model to calibrate the impact of the IT Revolution on German productivity growth. However, apart from more efficient management practices (which our model takes into account), there are several specificities of the US economy (such as the fact that most major IT producers are American) which could imply that IT had a larger impact in the US than in Germany. Therefore, Row [2] reports our main results when we explicitly impose a German growth target of 8.5%, almost 3 percentage points lower than in the baseline calibration (63% of the US number instead of 82%). We recalibrate the model using the new growth target and otherwise proceed as in our baseline calibration. This more conservative scenario does not change the relative growth rates of Southern European countries: as in our baseline calibration, Italy's growth rate is a little more than half of the German one, and Spain's a little less than a quarter. However, as absolute growth rates are lower, the IT Revolution explains a slightly smaller share of the actually observed productivity divergence: 26% in Italy, 35% in Spain and 61% in Portugal.

In Rows [3] and [4], we change the parameter values that govern the shape of the firm size distribution, namely the elasticity of substitution (increased to $\varepsilon = 4$) and the shape parameter of the Pareto distribution (lowered to $k = 3$). Again, all other external parameters are set to their baseline values and the model is recalibrated to the baseline targets. Both changes make the firm size distribution more right-skewed and slightly lower our divergence estimates. Indeed, with a more right-skewed firm size distribution, heterogeneous adoption rates and composition changes matter less, and aggregate divergence estimates become closer to the firm-level estimates discussed in the previous section. In the extreme case in which production were carried out by one single firm and

Table 9: Robustness checks

		Growth rates				Relative growth			Diverg. explained		
		DEU	ITA	PRT	ESP	ITA	PRT	ESP	ITA	PRT	ESP
[1]	Baseline	11.1%	5.9%	3.4%	2.5%	53%	31%	23%	35%	81%	47%
[2]	8.5% growth in Germany	8.5%	4.6%	2.7%	2.0%	54%	32%	24%	26%	61%	35%
[3]	$\varepsilon = 4$	11.8%	7.7%	5.4%	4.4%	66%	46%	37%	27%	68%	40%
[4]	$k = 3$	11.3%	6.4%	3.9%	3.0%	57%	35%	27%	33%	78%	45%
[5]	$\alpha_0 = 0.13$	11.1%	5.9%	3.4%	2.5%	53%	31%	23%	35%	81%	47%
[6]	$\alpha_0 = 0.09$	11.1%	5.9%	3.4%	2.5%	53%	31%	23%	35%	81%	47%
[7]	WMS w/o multinationals	9.5%	4.3%	1.8%	1.3%	45%	19%	14%	35%	81%	44%
[8]	People management	8.6%	4.3%	2.2%	1.4%	50%	26%	17%	29%	67%	39%
[9]	40% IT Empl. share	10.9%	5.5%	3.1%	2.2%	51%	28%	20%	36%	83%	47%
[10]	70% IT Empl. share	11.4%	6.6%	4.1%	3.1%	58%	36%	27%	32%	78%	45%
[11]	ERP complementarity	10.0%	3.5%	1.1%	0.4%	35%	11%	4%	44%	95%	53%
[12]	$\alpha_1 = 0.05$	11.2%	6.1%	3.6%	2.6%	54%	32%	24%	34%	81%	46%
[13]	Full period (1995-2015)	13.9%	7.5%	4.3%	3.1%	54%	31%	22%	30%	68%	51%

there were no migration, they would coincide.

Rows [5] to [8] report a line of robustness checks for management scores. In our baseline calibration, we set the management score of firms producing with the basic technology to -1.11, and therefore α_0 to 0.111. In Rows [5] and [6], we increase or decrease this baseline number, showing that this hardly affects our estimates. In Rows [7] and [8], we instead use different types of management scores to calibrate our model. Row [7] uses management scores that ignore multinational firms and control for cross-country differences in sample selection, as provided in Bloom et al. (2016, Table 7). Row [8] replaces the general management score by the sub-score for "people management", which has been shown to be particularly important for the interaction with IT (Bloom et al., 2012). Neither of these two alternatives changes our results substantially.

Rows [9] to [12] report robustness checks on the IT calibration. Rows [9] and [10] consider different targets for the employment share of IT-using German firms, showing that this hardly changes our baseline results. In Row [11], we consider the value for the parameter α_3 implied by our estimates for ERP software in Table 2, $\alpha_3 = 2.382$. This estimate is substantially higher than the one used in our baseline parametrization. As α_3 captures the degree of management-IT complementarity, this higher value obviously implies a higher divergence estimate, but nevertheless, magnitudes remain comparable. In Row [12], we set $\alpha_1 = 0.05$, that is, we assume that the direct effect of management on productivity is lower than in the baseline.

Finally, in Row [13], we report our results for a calibration for the full period 1995-2015 (described in greater detail in Appendix B). These results are very similar to our baseline estimates for the shorter period 1995-2008, with the share of divergence explained by our model being somewhat smaller in Italy and Portugal, and somewhat larger in Spain.

Overall, these results suggest that the IT Revolution can explain a sizeable part of Southern Europe's divergence with respect to Germany between 1995 and 2008. Across different parametrizations, it consistently accounts for around 26 to 36% of Italy's divergence, 35 to 47% of Spain's divergence, and 61 to 83% of Portugal's divergence. In the next section, we briefly discuss whether simple subsidy policies could improve Southern Europe's situation.

4.3.2 The effect of IT, management and education subsidies

IT and management adoption subsidies In our model and in the data, Southern European countries have lower IT adoption rates than Northern ones. Therefore, it seems natural that governments would try to reduce this gap by subsidizing IT adoption. IT subsidies are indeed a common industrial policy tool.[38] What would be the impact of such subsidies in our model?

To answer this question, we extend our model to include a government which levies a proportional tax on wages and uses it to finance an IT adoption subsidy τ_{IT}, reducing firms' effective fixed cost of IT adoption to $(1 - \tau_{IT}) f_{IT} w_H^S$. The extended model is presented in greater detail in Appendix B. Table 10 shows the outcome of the policy, calibrated so that tax revenue represents 1% of national income. The ensuing IT subsidy is large (covering between 27 and 41% of firms' adoption costs), and indeed increases IT adoption: the employment share of firms using IT increases by almost

[38]For example, Italy introduced in 2016 a generous tax credit for capital investments related to "Industry 4.0", aimed at digitalization, automation and data exchange for production in manufacturing. While there is yet no official data on take-up rates, anecdotal evidence suggest that they are substantial. The Spanish government is considering similar policies.

10 percentage points in all countries. However, the policy actually reduces aggregate productivity by 0.32% in Italy, and by 0.51% in Spain. Furthermore, it has a strong effect on the income distribution: as it stimulates the demand for high-skilled workers, it leads to a increase in the net high-skilled wage (and a fall in emigration), whereas net low-skilled wages fall.

We also consider a similar experiment with a management adoption subsidy τ_M (reducing firms' effective cost of management adoption to $(1 - \tau_M) f_M w_H^S$), calibrated to correspond to the same share of tax revenue in national income. This subsidy has an even worse effect on aggregate productivity. Redistributive effects are similar to the IT subsidy, but the increase in high-skilled wages is now smaller, and the decrease in low-skilled wages is stronger. Management adoption increases, but IT adoption falls, because the higher skill premium makes adoption less attractive.

Table 10: The effect of subsidies for IT and management adoption

	IT subsidy			Management subsidy		
	Italy	Portugal	Spain	Italy	Portugal	Spain
Tax revenue (% of national income)	1%	1%	1%	1%	1%	1%
τ_M	0	0	0	0.415	0.475	0.510
τ_{IT}	0.273	0.356	0.405	0	0	0
Change in productivity	-0.32%	-0.43%	-0.51%	-0.52%	-0.61%	-0.67%
Change in empl. share of firms with management	+2pp	+2pp	+2pp	+13pp	+15pp	+16pp
Change in empl. share of firms with IT	+8pp	+9pp	+9pp	-2pp	-1pp	-1pp
Change in net high-skilled wages	+0.7%	+0.6%	+0.5%	+0.6%	+0.5%	+0.5%
Change in net low-skilled wages	-0.6%	-0.7%	-0.8%	-0.8%	-0.9%	-1.0%
Change in emigration	-20%	-13%	-11%	-18%	-12%	-10%

Note: All changes are with respect to our baseline calibration with IT, and without taxes and subsidies. Productivity is measured as output per worker. The change in emigration refers to the percentage change in the absolute number of emigrants.

The fact that adoption subsidies reduce output and productivity is not surprising. Indeed, there are no externalities or distortions in our model,[39] so that the market allocation of resources is optimal, and IT or management subsidies inefficiently use up resources that would have had a

[39] To be precise, there is one distortion, namely the monopoly power of firms. However, because all firms charge the same markup and labour supply is inelastic, this has no effect on aggregate output.

higher marginal product elsewhere. Of course, in the presence of externalities and spillovers, which may be important for some IT technologies in the real world, subsidies would become useful again. Thus, our policy simulations should be taken with a grain of salt. Nevertheless, they do stress a key implication of our analysis: low IT adoption is a symptom of Southern European problems rather than the problem in itself. Thus, while subsidizing IT adoption will certainly reduce the delay in IT diffusion with respect to other advanced economies, the aggregate effects of such a policy will be limited, if not reversed, by management-IT complementarities.

Education subsidies Alternatively, we consider subsidies to education. Precisely, we assume that the government levies a lump-sum tax t on wages and uses the proceeds to pay a lump-sum subsidy s to all workers that become high-skilled. This can be interpreted as the equivalent of an education subsidy, such as for example free higher education, government-provided scholarships or subsidies for student loans. Details on this model are presented in Appendix B.

Table 11 shows the impact of an education subsidy calibrated such that the lump-sum tax represents 5% of the wage of low-skilled workers. This subsidy does not improve Southern Europe's situation: even though the high-skilled share of the workforce increases, output per capita decreases. Furthermore, as the policy directly redistributes resources from low to high-wage workers, it is regressive. The most noticeable effect of the policy is a large increase in emigration of high-skilled workers, which triples in Italy and more than doubles in Portugal and Spain. This suggests that in the presence of worker mobility (which is relatively high in the European Union), subsidizing education in the South may effectively only result in a transfer to the North, which benefits from the emigration of workers educated in the South.

Alternatively, the education subsidy could be limited to workers that do not emigrate.[40] Table 11 shows that this would somewhat improve its impact on aggregate productivity, as migration would now be roughly unchanged.[41] Yet, the overall effect remains negative, for the same reason as for the

[40]A policy of this type could be implemented by granting a temporary income tax exemption after graduation. Italy has a policy of this type for high-skilled foreign residents that choose to move to Italy: these pay income tax only on a fraction of their income (from 10% for researchers to 50% for graduates in general) during four years.

[41]With conditional subsidies, high-skilled emigration is driven by two effects. On the one hand, the increasing supply of high-skilled labour lowers the high-skilled wage in the South, and increases the incentives for emigration. On the other hand, the subsidy, which can only be perceived when staying in the South, decreases the incentives for emigration. Table 11 shows that the net effect of the policy is a slight decrease of the Southern net high-skilled wage (after subsidies), and therefore a slight increase in emigration. With unconditional subsidies, emigration gets more attractive, as it does not entail the loss of the subsidy any more.

IT and management subsidies: the education choices of Southern European workers were optimal to start with, and the subsidy distorted them.

Table 11: The effect of education subsidies

Beneficiaries of the subsidy	All high-skilled workers			Non-emigrants only		
	Italy	Portugal	Spain	Italy	Portugal	Spain
Tax (% of low-skilled wage)	5%	5%	5%	5%	5%	5%
Subsidy (% of high-skilled wage)	17%	18%	19%	18%	19%	19%
Change in productivity	-0.88%	-0.91%	-0.93%	-0.58%	-0.61%	-0.62%
Change in the share of high-skilled workers	+4pp	+4pp	+4pp	+4pp	+4pp	+4pp
Change in net high-skilled wages	-0.4%	-0.5%	-0.5%	-0.3%	-0.4%	-0.5%
Change in net low-skilled wages	-1.7%	-1.7%	-1.7%	-1.3%	-1.3%	-1.3%
Change in emigration	+200%	+138%	+125%	+4%	+3%	+3%

Note: All changes are with respect to our baseline calibration with IT, and without taxes and subsidies. Subsidies for high-skilled workers are stated net of taxes. Productivity is measured as output per worker. The change in emigration refers to the percentage change in the absolute number of emigrants.

In sum, simple subsidy policies do not improve Southern Europe's situation in our model. Instead, the first-best policy would aim to improve management practices. Our results indicate that policies improving management would have a large effect: Table 8 shows that if Southern European countries could achieve German management scores, they would increase their productivity by between 6 and 11%. Such a policy would increase the skill premium, but while subsidies achieved this by lowering the wage of low-skilled workers, improvements in management practices make everyone better off. Obviously, improving management practices is also harder than subsidizing IT adoption or education, as the determinants of cross-country differences in management efficiency are still poorly understood. However, the large pay-offs of such measures should put them in the focus of both researchers and policy makers.

5 Conclusions

Southern Europe's recent slowdown in productivity growth and the ensuing divergence with the rest of the OECD can be partially explained by the interaction between the IT Revolution and the inefficient management practices of Southern European firms. Indeed, we have argued in this paper that the appearance of IT, which has strong complementarities with management practices, stimulated income and productivity growth in Southern Europe less than in other countries. Our quantitative analysis suggests that across different countries and parametrizations considered, this mechanism can explain more than one third of the aggregate productivity divergence of Southern Europe with respect to Germany between 1995 and 2008. This result is driven by differences in adoption rates, differences in firm-level productivity gains, and the increase in the aggregate importance of management. Divergence has also amplified the emigration of high-skilled workers from the South.

To realize the full potential of IT and retain their most talented workers, Southern European countries need to solve their management problems. Our results show that the gains from improving management are large. Thus, uncovering the deep determinants of differences in management efficiency across countries is a very important topic for future research.

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A Data Appendix

A.1 Data sources

A.1.1 The management, IT and productivity dataset

The analysis of the complementarities between management and IT is based on a dataset that matches three firm-level data sources: the WMS dataset on management scores, data from Bureau Van Dijk on firm accounts, and the HH data on IT adoption. The data have been used in Bloom et al. (2012) and Bloom et al. (2016) and are extensively described in the online appendices of those papers. In particular, they show that selection is unlikely to be a major issue for both the WMS and the HH survey. In the following, we briefly describe the data, focusing on the aspects that are new with respect to the existing literature.

The World Management Survey We measure the efficiency of management practices by using management scores from the WMS survey, described in Section 2.1. The original data has 15.000 observations for 28 countries. We standardize the management scores and only keep OECD members, excluding emerging or transition economies (Chile, Mexico, Poland and Turkey). Table A.1 reports the number of observations, average firm size and the percentiles of of the standardized management score for each country.

Table A.1: Descriptive statistics for the WMS

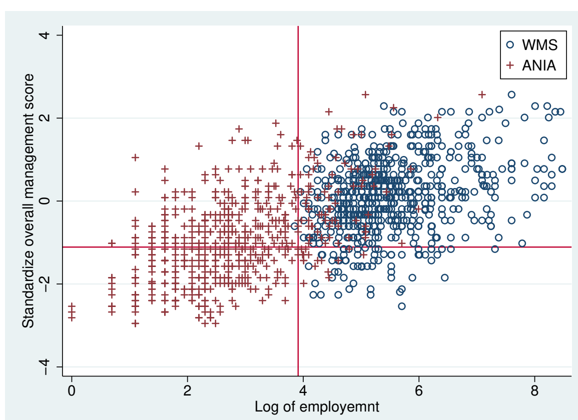
Country	N. obs	Avg N. workers	Management score		
			P25	Median	P75
United States	1,564	1284.78	-0.02	0.64	1.22
Japan	178	476.44	-0.02	0.39	1.11
Germany	749	930.93	-0.11	0.47	1.05
Sweden	404	514.96	-0.02	0.47	0.97
Canada	419	684.93	-0.35	0.31	1.05
Great Britain	1,540	764.31	-0.44	0.23	0.82
France	780	758.30	-0.41	0.14	0.72
Australia	473	1218.65	-0.44	0.23	0.72
Italy	632	448.99	-0.44	0.06	0.72
New Zealand	151	260.49	-0.60	-0.11	0.47
Portugal	410	344.21	-0.77	-0.11	0.56
Ireland	161	505.19	-1.10	-0.27	0.56
Spain	214	293.70	-0.85	-0.23	0.47
Greece	585	340.77	-1.01	-0.35	0.39

Source: WMS and authors' calculations.

The number of observations vary from 151 in New Zealand to 1564 in the United States. The table shows that average firm size is substantially lower in Southern Europe than in other countries, in line with the evidence from the general population of firms (however, as we have shown in the main text, these composition differences are not the main driver of differences in management scores). Table A.1 shows that the country ranking based on median management scores is very similar to rankings based on the 25th or the 75th percentile of the distributions. Moreover, the interquartile range is also similar across countries. In particular, for the countries used in our analysis, it is 1.24 for the United States, 1.16 for Germany, 1.16 for Italy, 1.32 for Spain and 1.33 for Portugal. This suggests that the management score distribution shifts with its mean, and that we capture the most important dimension of cross-country heterogeneity by focusing on the latter.

In order to measure the WMS scores of firms without formal management, we rely on the ANIA survey, described in detail in Guiso et al. (2015). The ANIA survey is based on a sample of Italian firms which were interviewed in 2008 and 2009 to score their managerial practices. The survey used the WMS protocol, under the training and supervision of Renata Lemos from the WMS team, to ensure comparability with the original WMS survey. The final sample consists of 612 firms. Compared to the original WMS, the ANIA survey focusses on small and medium enterprises: average employment is 32, median employment is 15 and 82% of firms have less than 50 employees. To ensure comparability with the original data, we standardize the management score using the same average and standard deviation of the overall sample. Figure A.1 plots the management scores of Italian firms from the ANIA survey (marked by a red cross) and from the WMS (marked by a blue circle) against the natural logarithm of firm employment. This clearly illustrates the differences in the survey frame of the two datasets. It also shows that there is a positive relationship between size and management scores, and that there is no discontinuity in this relationship when going from one survey to the other. This indicates that the two surveys can be meaningfully compared.

Figure A.1: Management scores for Italian firms: ANIA survey and WMS



Source: Authors' calculations using data from the WMS and Guiso et al. (2015). The vertical line corresponds to the 50 employees threshold, while the horizontal line is the average score for firms with less than 50 employees, equal to -1.11.

The Harte-Hanks Database The IT indicators used to study the complementarity between management and IT come from the international consulting company Harte-Hanks (HH). HH targets plants with at least 100 employees and collects detailed information on hardware and software to provide consulting services to IT producers. HH data have been extensively used in the literature as a source of information on IT at the firm-level (see, among others, Bresnahan et al., 2002; Bloom et al., 2012, 2016). We focus on software, which is classified into 14 different categories (including ERP, SCM, Communication software, Office applications, Storage, Security etc.). For each item, HH gives the number of production sites that use the software, and we define a firm-level adoption rate as the percentage of sites of the firm which use the software. Given that firms are surveyed with gaps, we extend the data using linear interpolation at the level of the firm. We only keep firms that have been surveyed at least once in the WMS and that also are matched to the Bureau Van Dijk database. This database, commercialized under the name ORBIS (see https://www.bvdinfo.com/it-it/home), contains balance sheet and income statement information for a large number of registered firms in many countries of the world. Table A.2 reports the sample composition at the country level for the HH observations which could be matched, together with average firm size.

Table A.2: Number of observations, time coverage and average firm size by country, HH sample

	N. obs.	First year	Last year	Avg. employment
France	1,128	2003	2015	384
Germany	1,011	2001	2015	1203
Great Britain	2,278	2003	2014	584
Italy	260	2000	2015	445
Poland	474	2002	2015	475
Portugal	503	2006	2015	280
Spain	578	2000	2014	335
Sweden	1,209	2001	2015	387
United States	1,732	2000	2015	3401

Source: HH.

Finally, Table A.3 reports summary statistics for all variables used in our management-IT complementarity regressions shown in Table 2, including the balance sheet variables.

Table A.3: Summary statistics for variables used in Table 2

	Mean	P25	Median	P75	S.D.
Natural logarithm of VA per worker	11.177	10.831	11.191	11.552	0.752
Management score	-0.029	-0.621	-0.003	0.616	0.930
Natural logarithm of capital per worker	11.140	10.474	11.165	11.841	1.192
Natural logarithm of employment	5.835	4.990	5.580	6.460	1.271
Overall IT	0.327	0.135	0.308	0.462	0.255
Overall IT · Management score	0.001	-0.135	0.000	0.146	0.379
ERP	0.419	0.000	0.500	0.500	0.342
ERP · Management score	0.001	-0.164	0.000	0.174	0.488

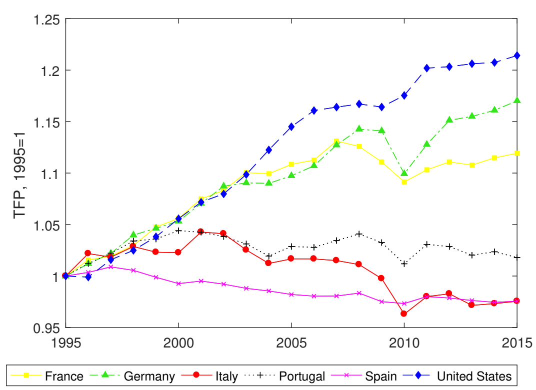
Source: HH, Bureau Van Dijk and WMS.

A.1.2 OECD Productivity Database

The productivity data used in Figures 1 and 3 and for the quantitative assessment of divergence in the data comes from the OECD Productivity Database (available at http://www.oecd.org/std/productivity-stats/). The data is described in greater detail in OECD (2017), and is available for all countries used in our analysis between 1985 and 2015. The only exception is New Zealand, where data starts in 1987. Thus, in Panel A of Figure 3, New Zealand's growth rate is calculated for the time period 1987-1995.

The basic productivity measure provided by the OECD is labour productivity, defined as real GDP per hour worked. This measure can be decomposed into three components: growth in "multifactor productivity" (the OECD's measure of TFP), Information and Communications Technology (ICT) capital deepening, and non-ICT capital deepening. Our preferred measure of productivity, shown in Figure 1, is calculated as the sum of the first and the second component. Note that the OECD measure focuses on ICT, whereas the focus of our paper mainly lies on IT. However, this is unlikely to affect our results in a substantial way. Indeed, most cross-country differences can be traced back to changes in TFP, as shown in Figure A.2.

Figure A.2: TFP growth in Southern Europe

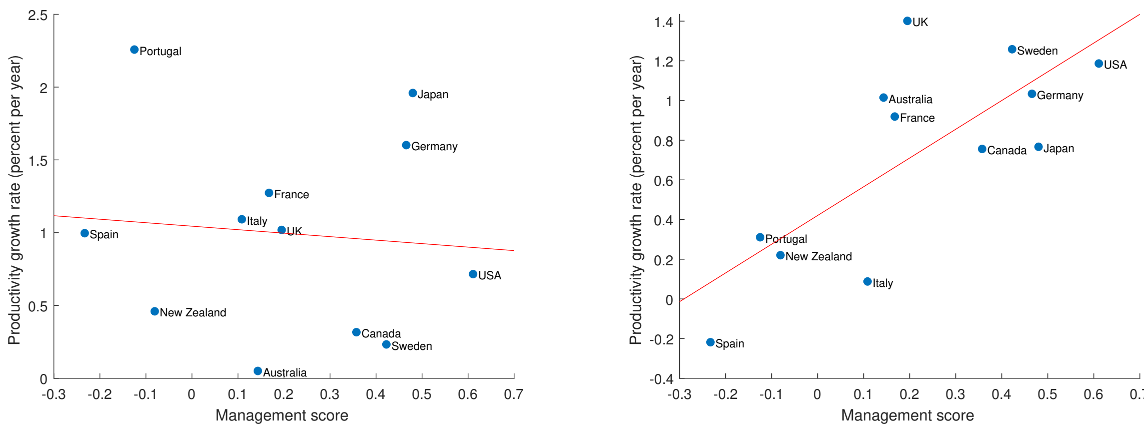


Source: OECD.

Figure A.3 replicates Figure 3 using TFP growth. There is a clear positive correlation between management scores and TFP growth between 1995 and 2008, and no such correlation between 1985 and 1995. Note that in Figures 3 and A.3, we omit Greece (which does not have productivity data) and Ireland. Ireland is a major outlier, with productivity growth rates substantially above the ones of all other countries (around 3% per year). However, it is well known that the large operations of multinational firms in Ireland make growth accounting challenging and difficult to interpret.

Figure A.3: Management scores and TFP growth

Panel A: 1985-1995 Panel B: 1995-2008



Source: OECD and WMS.

A.1.3 EU KLEMS

We use the EU KLEMS database to compute the IT capital stocks shown in Figure 1. The database can be accessed online at http://www.euklems.net/, and is described in greater detail in Jäger (2017). We use the September 2017 release of the database, and compute IT capital is the sum of the capital stocks for "Computing Equipment" and "Computer software and databases".

A.1.4 Database on Immigrants in OECD Countries

The migration data analysed in Section 2.3 comes from the OECD's Database on Immigrants in OECD Countries (DIOC). The database is constructed using national censuses and labour market surveys and can be accessed at http://www.oecd.org/els/mig/dioc.htm. The same website also contains a detailed description of data construction and of all variables.

For our purposes, we focus on the 2000/2001 and 2010/2011 editions of the database, using the version containing both the education level of migrants and their duration of stay (File B_T for the 2000/2001 edition, and File B for the 2010/2011 edition). This data set contains the absolute number of immigrants older than 15 years for a large number of OECD countries, split up by country of birth, education level (low (up to lower secondary), medium (up to post-secondary non-tertiary) and high (tertiary)) and duration of stay (five years or less, five to ten years, more than ten years). To analyse migration patterns between Italy, Portugal, Spain and the rest of the G7 countries, we limit the sample to observations for which both the country of residence and of birth belongs to this group.[42]

We need to make some adjustments to the raw data. First, some countries report a certain number of immigrants with known country of birth, but unknown education level and/or duration of stay. We distribute these immigrants over the different education and duration categories by assuming

[42]There is almost no data for Japan, and we therefore drop it from the sample.

that their distribution across these categories is identical to the one observed for immigrants for which all data is available.[43] Second, some German data needs to be imputed, because information is only available for immigrants of certain education and duration categories. We impute immigration numbers for the missing categories by assuming that immigrants in Germany are distributed across categories in the same way as immigrants from the same country of birth in the other destination countries (aggregating across all destinations). The only country of birth for which this imputation is not feasible is Canada, because there is no information at all on Canadian immigrants in Germany. This is not a problem for our analysis, as we aggregate across all Northern countries to construct Table 3, and thus do not consider internal migration in the North. Third, Portugal in 2000/2001 has only data for immigration from Germany and France. Thus, Table 3 understates the increase in high-skilled emigration, by overstating Portuguese net high-skilled emigration in 2000/2001.
Table A.4 shows high-skilled migration flows by country. It shows that, as discussed in Footnote 14 in the main text, Southern Europe's emigration dynamics are mainly driven by Italy and Portugal, while Spain fares substantially better.

Table A.4: High-skilled migration patterns between Southern Europe and the North

	2000/2001		2010/2011	
	Net migration absolute	Net migration % of domestic high-skilled	Net migration absolute	Net migration % of domestic high-skilled
North	7614	0.01%	61788	0.05%
Spain	1905	0.03%	30437	0.34%
Italy	-9580	-0.25%	-68593	-1.20%
Portugal	60	0.01%	-23632	-2.36%

Notes: See Table 3.

A.1.5 Eurostat

We use the Eurostat structural business statistics (SBS) to pin down several moments for the calibration. This dataset can be freely accessed on the Eurostat website, at http://ec.europa.eu/eurostat/web/structural-business-statistics. Average firm size and exit rates are calculated using the "business demography" tables and refer to the business economy, excepting the activities of holding companies. Average firm size is calculated as the ratio between the total number of persons employed and the total number of firms.
In order to calculate employment shares for firms with 50 employees or more (our proxy for employ-

[43] In the United Kingdom in 2000/2001, this is not always possible, as education and/or duration of stay is sometimes unknown for almost all immigrants from a given country. In these cases, we assume that immigrants are distributed across education and duration categories in the same way as immigrants from the same country of birth in the other destination countries (aggregating across all destinations).

ment shares of firms with management) and employment shares of IT-using firms, we use data for the size distribution of firms in the business economy (excluding financial and insurance activities). These series are available from 2012 or 2013 onwards for most countries. To calculate employment shares for firms with IT, we weight the adoption rates in Table 1 by the employment share of the corresponding size classes in the reference population (firms with 10 employees or more). Given this reference population, our IT employment shares are likely to somewhat overstate the true ones. However, the robustness checks in Section 4.3 show that our results are not sensitive to this choice. Finally, in order to measure skill premia and the high-skilled share of the workforce, we use the EU Survey on Income and Living Conditions (SILC), which is also available on the Eurostat website, and described at http://ec.europa.eu/eurostat/web/income-and-living-conditions/data. High-skilled workers are defined as workers with a university education, and the skill premium is calculated as the difference between their average net annual income and the one of the rest of the population.

A.2 IT supply in Italy and Germany

Table A.5 provides further evidence for the claims about IT supply made in Section 2.2.2.

Table A.5: Supply-side barriers to IT adoption in Italy and Germany

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

Source: Research Data Centre of the Federal and Regional Statistical Offices, "*Nutzung von Informations - und Kommunikationstechnologien (IKT) in Unternehmen 2014*" (Germany), ISTAT (Italy), own calculations. Columns [1]-[2] report the fraction of firms of a given size class which have encountered difficulties in hiring IT specialists (only among for firms that tried to hire). Columns [3]-[4] show the share of firms which have access to a fixed internet connection, and Columns [5]-[6] report their maximum download speed. All statistics use survey weights. For clarity, we report unconditional summary statistics, but results are confirmed when we control for sectoral and geographical dummies.

B Theoretical Appendix

B.1 Derivation of the equilibrium conditions

In this section, we provide some further details on our model's equilibrium conditions described in Section 3.2. Throughout, we impose three parameter conditions:

$$\exp\left(\alpha_0 + \alpha_1 \xi\right) > 1 + \frac{1}{\eta} \tag{24}$$

$$\exp\left(\alpha_2 \varphi + \alpha_3 \xi \varphi\right) > 1 \tag{25}$$

$$f < \min\left(\frac{f_M}{\left(\frac{\exp(\alpha_0+\alpha_1\xi)}{1+\frac{1}{\eta}}\right)^{\varepsilon-1} - 1} ; \frac{f_M + f_{IT}}{\left(\frac{\exp(\alpha_0+\alpha_1\xi+\alpha_2\varphi+\alpha_3\xi\varphi)}{1+\frac{1}{\eta}}\right)^{\varepsilon-1} - 1} \right). \tag{26}$$

Equations (24) and (25) are necessary conditions for management and IT to lower the marginal cost of production. If this were not the case, no firm would ever adopt them. Equation (26) ensures that the fixed cost of production f is sufficiently low with respect to management and IT adoption costs, so that some firms want to produce with the basic technology.

Furthermore, we conjecture throughout that parameters are such that $\pi(1) < 0$, that is, that the firm with the lowest possible productivity draw does not make profits. We do not provide a parameter condition for this, but verify that it is indeed the case in every calibration we consider.

B.1.1 Profit functions and productivity cut-offs

Case 1 First, consider a case in which the skill premium holds $\frac{w_H}{w_L} \geq \eta\left(\exp\left(\alpha_0 + \alpha_1\xi + \alpha_2\varphi + \alpha_3\xi\varphi\right) - 1\right)$. In that case, we would have $\widetilde{\xi} \leq \widetilde{\varphi} \leq 1$: that is, the skill premium would be so high that neither management nor IT adoption lower firms' marginal costs, and therefore, $s_M = s_{IT} = 0$. However, it is easy to see that Equation (9) still holds, although A_M^* and A_{IT}^* are now not well defined.

Case 2 Next, consider the more interesting case in which $\frac{w_H}{w_L} < \eta\left(\exp\left(\alpha_0 + \alpha_1\xi + \alpha_2\varphi + \alpha_3\xi\varphi\right) - 1\right)$. This will be the case for all of our results in the baseline calibration and is implicitly assumed in the discussion in the main text in Section 3.2.1. Then, define the functions π_B, π_M and π_{IT} as the profits made by a firm producing respectively with the basic technology, management and no IT, and management and IT. Firms can choose one of these three options, or exit, which yields a profit of 0. Our conjecture on the firm with the lowest possible productivity draw implies this firm never produces. Now, note that all profit functions are increasing in idiosyncratic productivity A. Moreover, the slope of π_M exceeds the one of π_B, and the slope of π_{IT} exceeds the one of π_M. Therefore, for a sufficiently large idiosyncratic productivity draw, π_B will become larger than 0, π_M will become larger than π_B, and π_{IT} will become larger than π_M. Therefore, the firms with the highest draws always choose to produce with both management and IT. Between these two extremes, firm behaviour is determined by the relative positions of the intersections of the three profit functions with each other and with the 0 line.

Define A^* as the productivity level holding $\pi_B(A^*) = 0$, which yields Equation (9) in the main text. Then, parameter condition (26) implies

$$\max\left(\pi_M(A^*)\ ;\ \pi_{IT}(A^*)\right) < 0. \tag{27}$$

Thus, at the point A^* where π_B crosses the 0 line, π_M and π_{IT} are still negative.[44] Accordingly, for every productivity draw A holding $1 \leq A < A^*$, all three profit functions are negative, and the best option is to exit the market. Firms with productivity equal to or slightly above A^* instead produce without adopting management and IT.[45] However, as π_M and π_{IT} have higher slopes than π_B, they must eventually cross this curve. Here, we need to distinguish two subcases.

Case 2.1 Assume first that in equilibrium, we have $\left(\widetilde{\varphi} - \widetilde{\xi}\right) f_M < \left(\widetilde{\xi} - 1\right) f_{IT}$. Then, define A_M^B as the productivity level holding $\pi_B\left(A_M^B\right) = \pi_M\left(A_M^B\right)$. It is then easy to show that $\pi_{IT}\left(A_M^B\right) < \pi_M\left(A_M^B\right)$. Thus, at the point $A_M^B > A^*$ where π_M crosses π_B, π_{IT} still lies below π_M. This implies that for every productivity draw A holding $A^* \leq A < A_M^B$, producing with the basic technology is the best option. However, for firms with productivity equal to or slightly above A_M^B, the best option is to produce with management, but without IT. Eventually, of course, π_{IT} will cross π_M, at the point A_{IT}^M defined by $\pi_M\left(A_{IT}^M\right) = \pi_{IT}\left(A_{IT}^M\right)$. Thus, firms with productivity draws A holding $A_M^B \leq A < A_{IT}^M$ will produce using management, but no IT, while firms with productivity draws $A \geq A_{IT}^M$ produce using management and IT.

Summarizing, firm behaviour is defined by three cut-offs $A^* < A_M^* < A_{IT}^*$, where the management and IT cut-offs are given by $A_M^* = A_M^B$ and $A_{IT}^* = A_{IT}^M$ (yielding Equation (10) in the main text).

Case 2.2 Now, consider the complementary case where we have $\left(\widetilde{\varphi} - \widetilde{\xi}\right) f_M < \left(\widetilde{\xi} - 1\right) f_{IT}$. In this case, we have $\pi_{IT}\left(A_M^B\right) \geq \pi_M\left(A_M^B\right)$. That is, at the point A_M^B at which π_M crosses π_B, π_{IT} already lies above π_M. This implies that producing with management but without IT is a dominated option which is never chosen by any firm. Instead, firms directly pass from producing with the basic technology to producing with management and IT, as soon as their productivity is higher than A_{IT}^B, defined by $\pi_B\left(A_{IT}^B\right) = \pi_{IT}\left(A_{IT}^B\right)$.

Summarizing, firm behaviour is defined by two cut-offs $A^* < A_M^* = A_{IT}^*$, where the common management and IT cut-off is given by $A_M^* = A_{IT}^* = A_{IT}^B$ (yielding Equation (11) in the main text).

[44]To prove Equation (27), note that $\pi_M(A^*) < 0$ if and only if $f < \frac{\frac{w_H}{w_L} f_M}{\widetilde{\xi}-1}$. Using the definition of $\widetilde{\xi}$, it is straightforward to see that this condition always holds, because $\frac{\frac{w_H}{w_L} f_M}{\widetilde{\xi}-1} = \frac{\frac{w_H}{w_L} f_M}{\left(\frac{\exp(\alpha_0+\alpha_1\xi)}{1+\frac{w_H}{\eta w_L}}\right)^{\varepsilon-1} - 1} > \frac{f_M}{\left(\frac{\exp(\alpha_0+\alpha_1\xi)}{1+\frac{1}{\eta}}\right)^{\varepsilon-1} - 1} > f$, where the last inequality comes from the parameter condition in Equation (26).

[45]We assume, without loss of generality, that firms which are indifferent between two options always choose the more advanced one. This does not matter for the results, as the mass of firms which are indifferent between options is zero.

We have now fully characterized the decision rules of firms as a function of parameters and of the skill premium. Using the free-entry condition, we can furthermore derive Equation (15), which gives the exit cut-off A^* as a function of the skill premium. Using the fact that

$$\int_{A^*}^{+\infty} A^{\varepsilon-1} dG(A) = \int_{A^*}^{+\infty} kA^{\varepsilon-k-2} dA = \frac{k}{k-(\varepsilon-1)} A^{*\varepsilon-1-k}.$$

we can rewrite the free-entry condition as

$$\begin{aligned} f_E \frac{w_H}{w_L} = \; & A^{*-k} \frac{k}{k-(\varepsilon-1)} \frac{B}{w_L} w_L^{1-\varepsilon} \left(A^{*\varepsilon-1} + \left(\widetilde{\xi}-1\right) A_M^{*\varepsilon-1} \left(\frac{A^*}{A_M^*}\right)^k + \left(\widetilde{\varphi}-\widetilde{\xi}\right) A_{IT}^{*\varepsilon-1} \left(\frac{A^*}{A_{IT}^*}\right)^k \right) \\ & + A^{*-k} \left(f + \frac{w_H}{w_L} \left(\left(\frac{A^*}{A_M^*}\right)^k f_M + \left(\frac{A^*}{A_{IT}^*}\right)^k f_{IT} \right) \right) \end{aligned} . \quad (28)$$

Combining this expression with the definition of the productivity cut-offs and with the definitions of s_M and s_{IT} yields Equation (15) in the main text. Note that this Equation holds in all cases discussed here (1, 2.1 and 2.2).

We now proceed to determine the labour market clearing conditions, which pin down the skill premium. Once we have characterized these conditions, we will be able verify our initial conjecture, $\pi(1) < 0$.

B.1.2 Labour demands

To compute labour demands, we distinguish four groups of firms.

Firms which do not produce These firms (which exit immediately after learning their productivity draw) do not demand low-skilled labour, but only high-skilled labour for their entry cost. Thus, we have

$$\begin{aligned} L_{\text{NoProd}} &= 0 \\ H_{\text{NoProd}} &= \frac{G(A^*)}{1-G(A^*)} M f_E \end{aligned} , \quad (29)$$

which uses the fact that the mass of firms paying the entry cost equals $\frac{M}{1-G(A^*)}$.

Firms which produce with the basic technology These firms demand low-skilled labour for production and for the production fixed cost, and high-skilled labour for the entry cost. Precisely, the low-skilled labour demand for production demanded by a firm of productivity A is equal to $(\varepsilon-1)\left(\frac{A}{w_L}\right)^{\varepsilon-1} \frac{B}{w_L}$. Aggregating this labour demand up among all firms, and adding the demand for fixed costs, we get

$$L_B = (1-s_M) M \left(\left(\int_{A^*}^{A_M^*} (\varepsilon-1) \left(\frac{A}{w_L}\right)^{\varepsilon-1} \frac{B}{w_L} \frac{g(A)}{G(A_M^*) - G(A^*)} dA \right) + f \right).$$

Solving for the integral and using the definition of the exit cut-off in Equation (9), we get

$$L_B = Mf\left(\frac{k(\varepsilon-1)}{k-(\varepsilon-1)}\left(1-(s_M)^{1-\frac{\varepsilon-1}{k}}\right)+(1-s_M)\right). \tag{30}$$

Finally, the aggregate high-skilled labour demand of firms producing without management is just

$$H_B = (1-s_M)\,Mf_E. \tag{31}$$

It can be shown that these expressions hold in all three cases distinguished in Section B.1.1. In Case 1, $s_M = 0$, in Case 2.1, s_M is given by Equation (12), and in Case 2.2, s_M is given by Equation (13).

Firms which use management, but no IT These firms demand low-skilled labour for production and for the production fixed cost, and high-skilled labour for managers, the entry cost and the fixed cost of management. It is easy to show that the low-skilled labour demand for production demanded by a firm of productivity A is given by $(\varepsilon-1)\frac{\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}\left(\frac{A}{w_L}\right)^{\varepsilon-1}\frac{B}{w_L}$. Proceeding in the same way as for firms without management, we can aggregate low-skilled labour demand across all firms to get

$$L_{\text{MNoIT}} = (s_{IT}-s_M)\,M\left(\int_{A_M^*}^{A_{IT}^*}(\varepsilon-1)\frac{\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}\left(\frac{A}{w_L}\right)^{\varepsilon-1}\frac{B}{w_L}\frac{g(A)}{G(A_{IT}^*)-G(A_M^*)}dA+f\right).$$

Solving for the integral and using the definition of the exit cut-off in Equation (9), we get

$$L_{\text{MNoIT}} = Mf\left(\frac{k(\varepsilon-1)}{k-(\varepsilon-1)}\frac{\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}\left((s_M)^{1-\frac{\varepsilon-1}{k}}-(s_{IT})^{1-\frac{\varepsilon-1}{k}}\right)+(s_M-s_{IT})\right). \tag{32}$$

The high-skilled labour demand for management by these firms is just a multiple $\frac{1}{\eta}$ of their demand of low-skilled production labour. Adding to this the demand of high-skilled labour for entry costs and management fixed costs, we get

$$H_{\text{MNoIT}} = M\left(\frac{k(\varepsilon-1)}{k-(\varepsilon-1)}\frac{\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}\frac{f}{\eta}\left((s_M)^{1-\frac{\varepsilon-1}{k}}-(s_{IT})^{1-\frac{\varepsilon-1}{k}}\right)+(s_M-s_{IT})(f_E+f_M)\right). \tag{33}$$

Again, these expressions hold in all the three cases distinguished in Section B.1.1.

Firms which use both management and IT These firms demand low-skilled labour for production and for the production fixed cost, and high-skilled labour for managers, the entry cost, the fixed cost of management and IT. It is easy to show that the low-skilled labour demand for production demanded by a firm of productivity A is given by $(\varepsilon-1)\frac{\widetilde{\varphi}}{1+\frac{w_H}{\eta w_L}}\left(\frac{A}{w_L}\right)^{\varepsilon-1}\frac{B}{w_L}$. Thus, proceeding as before, we get

$$L_{\text{IT}} = Mf\left(\frac{k(\varepsilon-1)}{k-(\varepsilon-1)}\frac{\widetilde{\varphi}}{1+\frac{w_H}{\eta w_L}}(s_{IT})^{1-\frac{\varepsilon-1}{k}}+s_{IT}\right) \tag{34}$$

for the demand of low-skilled labour, and

$$H_{\text{IT}} = M\left(\frac{k(\varepsilon-1)}{k-(\varepsilon-1)}\frac{\widetilde{\varphi}}{1+\frac{w_H}{\eta w_L}}\frac{f}{\eta}(s_{IT})^{1-\frac{\varepsilon-1}{k}}+s_{IT}(f_E+f_M+f_{IT})\right) \tag{35}$$

for the demand of high-skilled labour.

Taking stock Summing up high-skilled labour demand over all four groups of firms, and using Equation (15) to simplify the resulting expression, we get

$$\begin{aligned} H^D = \; & M\left[\tfrac{k(\varepsilon-1)}{k-(\varepsilon-1)}\tfrac{f}{\eta+\frac{w_H}{w_L}}\left(\widetilde{\xi}(s_M)^{1-\frac{\varepsilon-1}{k}}+\left(\widetilde{\varphi}-\widetilde{\xi}\right)(s_{IT})^{1-\frac{\varepsilon-1}{k}}\right)\right. \\ & \left.+\left(\tfrac{\varepsilon-1}{k-(\varepsilon-1)}f\tfrac{w_L}{w_H}+\tfrac{k}{k-(\varepsilon-1)}(s_M f_M+s_{IT}f_{IT})\right)\right] \end{aligned}. \tag{36}$$

Likewise, summing up low-skilled labour demand across all four groups for firms, we get

$$L^D = M\left[f+\frac{k(\varepsilon-1)}{k-(\varepsilon-1)}f\left(1+\left(\frac{\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}-1\right)(s_M)^{1-\frac{\varepsilon-1}{k}}+\left(\frac{\widetilde{\varphi}-\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}\right)(s_{IT})^{1-\frac{\varepsilon-1}{k}}\right)\right]. \tag{37}$$

Taking the ratio of these two equations, we obtain Equation (16) in the main text. This equation, together with the relative supply of high-skilled labour defined by Equation (5), pins down the skill premium. Once we have solved for the latter, we can deduce the equilibrium value of the exit cut-off A^*. When the obtained value for A^* is larger than 1, then it must be that our initial conjecture $\pi(1) < 0$ holds. Otherwise, parameter values are not admissible, because they violate this conjecture.

Once we have solved for the skill premium, we can use Equation (5) to solve for the low-skilled labour supply L, which allows us to deduce the equilibrium value of M from Equation (37).

B.1.3 Worker decisions in Southern countries

We denote by I_L^S, I_H^S and I_H^N the incomes of an Southern worker as defined by her education and emigration choice. Given the structure of education and emigration costs, it is clear that a worker of type 0 chooses to supply low-skilled labour at home, while a worker of type 1 chooses to emigrate and to supply high-skilled labour in the North. Between these two extremes, there must necessarily be some workers which choose to supply high-skilled labour at home. Indeed, if no worker would choose that option, domestic high-skilled labour supply would be zero, which is impossible in equilibrium.[46]

[46]Indeed, migration costs imply that a Southern country never loses its entire population. This ensures that high-skilled labour demand is always positive, because high-skilled labour is needed to create firms.

Given the cost structure, it is clear that as we consider workers with higher types, both I_H^S and I_H^N will eventually exceed I_L^S, and I_H^N will eventually exceed I_H^S. Moreover, it is impossible that the crossing point for I_H^N and I_L^S lies to the left of the one for I_H^S and I_L^S, as this would imply that high-skilled labour supply is zero. Thus, the only possible constellation is that workers of types between 0 and $j^{S*} = \left(\frac{w_L^S}{w_H^S}\right)^{\frac{1}{\nu_1}}$ (the crossing point of I_H^S and I_L^S) choose to supply low-skilled labour at home, workers of types between j^{S*} and $j_E^{S*} = \left(\frac{w_H^S}{w_H^N}\right)^{\frac{1}{\nu_2}}$ (the crossing point of I_H^N and I_H^S) choose to supply high-skilled labour at home, and workers with types above j_E^{S*} choose to supply high-skilled labour in the North. This is the result stated in the main text.

With this, the Southern equilibrium can be computed as described in the main text. In all simulations, we verify that both high and low-skilled wages are indeed lower in Southern countries than in Northern ones, as we conjectured to solve the model.

B.1.4 Additional variables and calibration

The labour demands given in Section B.1.2 pin down the share of employment at different categories of firms, which is an important input for the calibration. However, the equations in the preceding section only give the units of high-skilled labour demanded by firms. Due to education costs, each high-skilled worker actually supplies less than one unit of labour. Thus, to determine the actual number of high-skilled workers at a given category of firms, we need to divide the above high-skilled labour demands by the units of high-skilled labour supplied by the average high-skilled worker. For Northern countries, this is $h = \frac{H}{1-j^*}$. For Southern countries, employment shares (and output per worker) need to be calculated taking into account that total population is not equal to 1 as in the North, but to $1 - j_E^{S*}$ (and therefore, $h^S = \frac{H^S}{j_E^{S*} - j^{S*}}$).
The calibration also targets average firm size. We define this statistic in the model as the average employment of producing firms, that is, as $\frac{1-(H_{\text{NoProd}}/h)}{M}$ for a Northern country and $\frac{j_E^{S*}-\left(H_{\text{NoProd}}^S/h^S\right)}{M^S}$ for a Southern country.

Finally, when solving the calibration problem defined by Equation (23), we introduce a weight equal to 10 for the aggregate growth rate, to be sure to match this crucial target exactly. Furthermore, we impose an upper limit of 100 for the parameter η, and an upper limit of 10 for all fixed costs.

B.2 A simplified model with an analytical solution

This section outlines a simplified version of our model allowing us to derive some analytical results. In this simplified model, we assume that workers are homogeneous, each supplying one unit of generic labour, and that migration is infinitely costly. All other assumptions are the same as in our baseline model (in particular, firms still need to hire labour for different tasks and fixed costs, but all labour requirements are now given in terms of generic labour).

B.2.1 Solution

In this simplified model, it is straightforward to check that Equations (9) to (13) still hold, just replacing high and low-skilled wages with the generic wage w. In particular, Equations (12) and (13) now indicate that the shares of firms using management and IT are fully pinned down by parameter values even before solving for the remaining endogenous variables. By using the free-entry condition, we then get an explicit solution for the exit cut-off, given by

$$A^* = \left(\frac{(\varepsilon - 1)(f + s_M f_M + s_{IT} f_{IT})}{(k - (\varepsilon - 1)) f_E} \right)^{\frac{1}{k}}. \tag{38}$$

Furthermore, using the national income identity $Y = wL$ and the definition of the auxiliary variable B, we get an explicit solution for the wage, given by

$$w = \frac{\varepsilon - 1}{\varepsilon} \left(\frac{1}{\varepsilon f} \right)^{\frac{1}{\varepsilon - 1}} A^*. \tag{39}$$

Finally, using the labour market clearing conditions, it is easy to show that the mass of active firms is given by

$$M = A^{*-k} \frac{\varepsilon - 1}{\varepsilon k f_E}. \tag{40}$$

B.2.2 Comparative statics

In this simple model, it is straightforward to prove that (as long as the equilibrium is such that some firms produce with the basic technology), the share of firms with management and IT is larger in the North, the exit cut-off is higher, wages are higher, and the mass of firms is lower. It is also straightforward to prove that an increase in the IT parameter φ increases the share of firms with IT, the exit cut-off and wages in all countries, while lowering the mass of active firms.

The relative wage of a Northern with respect to a Southern country is given by

$$\frac{w^N}{w^S} = \left(\frac{f + s_M^N f_M + s_{IT}^N f_{IT}}{f + s_M^S f_M + s_{IT}^S f_{IT}} \right)^{\frac{1}{k}}. \tag{41}$$

Using this expression, it is again straightforward to prove that $w^N > w^S$: this simply follows from the fact that a larger share of Northern firms adopt management and/or IT. Furthermore, it is also possible to show that the IT Revolution triggers divergence. Here, we prove divergence for the case in which, both in the North and in the South, not all firms that use management also use IT. Similar proofs apply for all other cases. Using Equation (41), it is easy to show that the ratio w^N/w^S is increasing in φ iff

$$\frac{\frac{\partial s_{IT}^N}{\partial \varphi}}{\frac{\partial s_{IT}^S}{\partial \varphi}} > \frac{f + s_M^N f_M + s_{IT}^N f_{IT}}{f + s_M^S f_M + s_{IT}^S f_{IT}}.$$

To show that this inequality holds, we proceed in two steps, showing

$$\frac{\frac{\partial s_{IT}^{N}}{\partial \varphi}}{\frac{\partial s_{IT}^{S}}{\partial \varphi}} > \frac{s_{IT}^{N}}{s_{IT}^{S}} > \frac{f + s_{M}^{N} f_M + s_{IT}^{N} f_{IT}}{f + s_{M}^{S} f_M + s_{IT}^{S} f_{IT}}. \tag{42}$$

Using the expression for the share of firms using IT, the first inequality reduces to

$$\frac{\left(\widetilde{\varphi}^{N} - \widetilde{\xi}^{N}\right)^{\frac{k}{\varepsilon-1}-1} \widetilde{\varphi}^{N}\left(\alpha_2 + \alpha_3 \xi^{N}\right)}{\left(\widetilde{\varphi}^{S} - \widetilde{\xi}^{S}\right)^{\frac{k}{\varepsilon-1}-1} \widetilde{\varphi}^{S}\left(\alpha_2 + \alpha_3 \xi^{S}\right)} > \frac{\left(\widetilde{\varphi}^{N} - \widetilde{\xi}^{N}\right)^{\frac{k}{\varepsilon-1}}}{\left(\widetilde{\varphi}^{S} - \widetilde{\xi}^{S}\right)^{\frac{k}{\varepsilon-1}}}$$

which can be rewritten as

$$\frac{\alpha_2 + \alpha_3 \xi^{N}}{1 - \exp\left(-\left(\varepsilon - 1\right)\varphi\left(\alpha_2 + \alpha_3 \xi^{N}\right)\right)} > \frac{\alpha_2 + \alpha_3 \xi^{S}}{1 - \exp\left(-\left(\varepsilon - 1\right)\varphi\left(\alpha_2 + \alpha_3 \xi^{S}\right)\right)}.$$

This inequality holds for all parameter values, because the function $g\left(x\right) = \frac{x}{1-\exp(-ax)}$ is increasing in x for any value (positive) value of x and for any value of the (positive) parameter a.[47] This completes the first part of the proof, by showing that the left-hand side inequality in Equation (42) holds.

To complete the proof, we now consider the right-hand side inequality. This can be rewritten

$$\frac{s_{IT}^{N}}{s_{IT}^{S}} > \frac{s_{IT}^{N}}{s_{IT}^{S}} + \frac{f\left(1 - \frac{s_{IT}^{N}}{s_{IT}^{S}}\right) + f_M\left(s_M^N - \frac{s_{IT}^{N}}{s_{IT}^{S}} s_M^S\right)}{f + s_M^S f_M + s_{IT}^{S} f_{IT}}.$$

To show that this inequality holds, it thus suffices to show that $f\left(1 - \frac{s_{IT}^{N}}{s_{IT}^{S}}\right) + f_M\left(s_M^N - \frac{s_{IT}^{N}}{s_{IT}^{S}} s_M^S\right) < 0$, which holds iff $\frac{f + s_M^N f_M}{s_{IT}^{N}} < \frac{f + s_M^S f_M}{s_{IT}^{S}}$. Using the expressions for the shares of firms with management and IT, this can be rewritten as

$$\frac{f + \left(\frac{\left(\widetilde{\xi}^{N}-1\right)f}{f_M}\right)^{\frac{k}{\varepsilon-1}} f_M}{\left(\widetilde{\xi}^{N}\left(\overline{\varphi}^{N} - 1\right)\right)^{\frac{k}{\varepsilon-1}}} < \frac{f + \left(\frac{\left(\widetilde{\xi}^{S}-1\right)f}{f_M}\right)^{\frac{k}{\varepsilon-1}} f_M}{\left(\widetilde{\xi}^{S}\left(\overline{\varphi}^{S} - 1\right)f\right)^{\frac{k}{\varepsilon-1}}},$$

where $\overline{\varphi} = \exp\left(\left(\varepsilon - 1\right)\varphi\left(\alpha_2 + \alpha_3 \xi\right)\right)$. To show that this final inequality holds, it suffices to show that the function $g\left(\xi\right) = \frac{f + \left(\frac{\left(\widetilde{\xi}-1\right)f}{f_M}\right)^{\frac{k}{\varepsilon-1}} f_M}{\widetilde{\xi}^{\frac{k}{\varepsilon-1}}} \cdot \frac{1}{\left(\overline{\varphi}^{N}-1\right)^{\frac{k}{\varepsilon-1}}}$ is decreasing in ξ. This is true because h is

[47] To see this, note that its derivative g' has the same sign as $h\left(x\right) = 1 - \left(1 + ax\right)\exp\left(-ax\right)$. This expression is increasing in x (which is easily verified by calculating its derivative, which equals $a^2 x \exp\left(-ax\right) > 0$). Furthermore, for $x = 0$, $h\left(x\right) = 0$. This proves that h, and therefore g', are always positive.

the product of two positive-valued and decreasing functions.[48]

B.3 Quantitative analysis for the period 1995-2015

In this section, we describe our calibration and quantitative results for the period 1995-2015. All externally calibrated parameters are unchanged with respect to the main text. For the internal calibration, we now use moments for the year 2015 (or the closest available year) instead of 2008. In particular, we set US productivity growth to 17% between 1995 and 2015.[49] All other data targets are listed in Table A.6, and taken from the same sources as in the main text.

Table A.6: Targeted moments, 1995-2015

Moment	Country	Data	Model
IT-induced productivity growth	United States	17.0%	17.0%
IT-induced productivity growth	Germany	n.a.	13.9%
Employment in firms with IT	Germany	60.0%	60.0%
Employment in firms with management	Germany	60.0%	60.0%
Average firm size (employees)	Germany	10.0	10.0
Exit rate	Germany	61.7%	61.6%
Percentage of high-skilled workers	Germany	24.4%	24.4%
Skill premium	Germany	43.1%	43.1%
Emigration (perc. of high-skilled pop.)	South	1.26%	1.26%

Note that we set the target for the employment share of IT-adopting firm to a slightly higher value than in the calibration for 1995-2008. We also adjust the target for the employment in firms with management: in the data, the employment share of firms with more than 50 employees in 2015 is

[48] The second term is obviously decreasing. Consider the first term, $h(\xi) = \frac{f + \left(\frac{(\tilde{\xi}-1)f}{f_M}\right)^{\frac{k}{\varepsilon-1}} f_M}{\tilde{\xi}^{\frac{k}{\varepsilon-1}}}$. Its derivative h' has the sign of $-f + \frac{s_M f_M}{\tilde{\xi}-1}$, which is negative iff $\left(\frac{(\tilde{\xi}-1)f}{f_M}\right)^{\frac{k}{\varepsilon-1}} < \frac{(\tilde{\xi}-1)f}{f_M}$. This always holds, as $\frac{(\tilde{\xi}-1)f}{f_M} < 1$ and $k > \varepsilon - 1$.

[49] This relies, as in the main text, on Table 1 in Byrne et al. (2013). We assume that the growth rates indicated by the authors for the period 2004-2012 continued to prevail in 2012-2015. This implies that real GDP per worker in the US nonfarm business sector grew by 44.7 log points during the period. Netting out the contribution of non-IT capital (8.1 log points), a productivity growth rate of 36.6 log points remains. As the total contribution of IT to growth in real GDP per worker during these years was 20.5 log points, it follows that IT accounted for 56% ($^{20.5}/_{36.6}$) of all productivity growth. Assuming that the same percentage holds for the overall economy, and noting that the OECD data discussed in the introduction implies that US productivity has increased by 27.9 log points between 1995 and 2015 yields an overall IT contribution of 15.7 log points ($0.56 \cdot 27.9$), or 17.0%.

57.2% in Germany, but we increase this to 60%, as our model implies that this employment share cannot be lower than the one of firms using IT.

Table A.7 shows the quantitative results for this calibration. For Italy, results are a little smaller than in the baseline, with the IT Revolution accounting for around 30% of total divergence. For Spain, the share of divergence explained by our model somewhat increases in this longer period. This is mostly due to the fact that the empirically observed divergence itself is smaller, because Spanish growth in output per hour worked has been relatively strong between 2008 and 2015.

Table A.7: Quantitative results for the period 1995-2015

	[1] Without IT				[2] With IT			
	DEU	ITA	PRT	ESP	DEU	ITA	PRT	ESP
Productivity (rel. to Germany)	1	0.987	0.981	0.978	1	0.931	0.898	0.885
Productivity growth					13.9%	7.5%	4.3%	3.1%
Share of empirical divergence						30%	68%	51%
Emp. in firms with management	31%	22%	16%	13%	60%	45%	34%	29%
Emp. in firms with IT	0%	0%	0%	0%	60%	45%	34%	29%
Skill premium	33%	32%	31%	31%	43%	39%	36%	35%
Share of high-skilled workers	20%	19%	19%	19%	24%	22%	21%	20%
Emigrants in the high-skill pop.	0%	0.2%	0.3%	0.4%	0%	0.8%	1.4%	1.6%
Emigrants in the total pop.	0%	0.0%	0.1%	0.1%	0%	0.2%	0.3%	0.3%

B.4 The model with subsidies

B.4.1 Subsides to management and IT adoption

In this subsection, we assume that Southern governments reimburse firms a fraction τ_M of their fixed costs of management adoption, and a fraction τ_{IT} of their fixed costs of IT adoption, where τ_M and τ_{IT} are parameters. These subsidies are financed by a proportional tax on all domestic workers.[50] In order to simplify notation, we omit Southern country superscripts in this extension.

[50]We choose a proportional tax because it simplifies exposition. Note that it is not distortionary in our setup (as labour supply is inelastic). Thus, aggregate results would be exactly the same with a lump-sum tax, but the distributional impact would be even more regressive.

Worker decisions Denoting the proportional tax rate by t, it is easy to see that the cut-offs for becoming high-skilled and for emigration are now given by

$$j^* = \left(\frac{w_L}{w_H}\right)^{\frac{1}{\nu_1}} \text{ and } j_E^* = \left(\frac{(1-t)\, w_H}{w_H^N}\right)^{\frac{1}{\nu_2}}. \tag{43}$$

Then, the domestic relative supply of high-skilled labour is given by

$$\frac{H}{L} = \frac{1}{1+\nu_1}\left(\frac{w_H}{w_L}\right)^{\frac{1}{\nu_1}}\left(\left(\frac{(1-t)\, w_H}{w_H^N}\right)^{\frac{1+\nu_1}{\nu_2}} - \left(\frac{w_L}{w_H}\right)^{\frac{1+\nu_1}{\nu_1}}\right), \tag{44}$$

and the domestic population size is $1 - j_E^*$.

Firm decisions Subsidies do not fundamentally change the problem of a firm, but just reduce the effective fixed costs of management and IT adoption. Thus, the analysis and formulas of the baseline model remain valid, just substituting $w_H f_M$ and $w_H f_{IT}$ by $(1-\tau_M)\, w_H f_M$ and $(1-\tau_{IT})\, w_H f_{IT}$ in the Equations defining the productivity cut-offs (Equations (10), (11) and (15)). The labour market clearing conditions can be shown to be the same as in Section B.4. Therefore, using the modified Equation (15) to simplify the resulting expression, we get

$$\frac{H}{L} = \frac{\frac{k(\varepsilon-1)f}{\eta+\frac{w_H}{w_L}}\left(\widetilde{\xi} s_M^{1-\frac{\varepsilon-1}{k}} + \left(\widetilde{\varphi}-\widetilde{\xi}\right) s_{IT}^{1-\frac{\varepsilon-1}{k}}\right) + \left((\varepsilon-1)\left(\frac{w_L}{w_H} f - \tau_M s_M f_M + \tau_{IT} s_{IT} f_{IT}\right) + k\left(s_M f_M + s_{IT} f_{IT}\right)\right)}{\left(k-(\varepsilon-1)\right) f + k(\varepsilon-1) f \left(1 + \left(\frac{\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}} - 1\right) s_M^{1-\frac{\varepsilon-1}{k}} + \left(\frac{\widetilde{\varphi}-\widetilde{\xi}}{1+\frac{w_H}{\eta w_L}}\right) s_{IT}^{1-\frac{\varepsilon-1}{k}}\right)}. \tag{45}$$

Solution Solving the model now requires to solve a three-equation system. The first equation is given by the relative labour market clearing condition, equalizing the relative supply of high-skilled labour (which depends on w_L, w_H and t) to the relative demand for high-skilled labour, which depends on w_L and w_H. The second equation is the government budget constraint. By definition, the proportional tax rate t must hold

$$t\left(w_L L + w_H H\right) = \left(s_M \tau_M f_M + s_{IT}\tau_{IT} f_{IT}\right) M w_H, \tag{46}$$

where M can be deduced from knowing w_L and w_H by using Equation (37).
The last equation is obtained by combining, as in the baseline model, the national income identity (which is now $Y = (1-t)\left(w_L L + w_H H\right)$) with the definition of the exit cut-off, yielding

$$w_L = \frac{\varepsilon-1}{\varepsilon} A^* \left(\frac{(1-t)\left(L + \frac{w_H}{w_L} H\right)}{\varepsilon f}\right)^{\frac{1}{\varepsilon-1}}. \tag{47}$$

This system can be solved numerically to obtain the solution for this extended model.

B.4.2 Subsides to education

Finally, we describe the model with education subsidies. We assume that the government charges a lump-sum tax t on all domestic workers, and uses it to redistribute subsidies to high-skilled workers. First, consider the case in which subsidies are perceived by all high-skilled workers, no matter whether they emigrate or not. Denoting the subsidy per person by s, it is then straightforward to show that the new cut-offs for becoming high-skilled and for emigrating are given by

$$j^* = \left(\frac{w_L - s}{w_H}\right)^{\frac{1}{\nu_1}} \text{ and } j_E^* = \left(\frac{w_H - t}{w_H^N}\right)^{\frac{1}{\nu_2}}. \tag{48}$$

On the firm side of the model, nothing changes. Thus, the solution of the model is given by a system of three equations in three unknowns (the Southern wage levels and the subsidy s). The three equations are the relative labour market clearing condition, the definition of the low-skilled wage of Equation (17), and the government budget constraint, which writes

$$s = \frac{t\,(1 - j_E^*)}{1 - j^*}. \tag{49}$$

This system can again be solved numerically.[51]

Second, consider the case in which subsidies are only perceived by high-skilled workers who stay in the South. Then, the cut-off for becoming high-skilled is still given by Equation (48), but the cut-off for emigration is given by

$$j_E^* = \min\left(\left(\frac{w_H + s - t}{w_H^N}\right)^{\frac{1}{\nu_2}}, 1\right). \tag{50}$$

The model can be solved just as before, taking into account that the government budget constraint is now

$$s = \frac{t\,(1 - j_E^*)}{1 - j^* - j_E^*}. \tag{51}$$

[51] Note that we assume that subsidies to emigrants are given in terms of domestic goods, i.e. that emigrants consume them at home. Therefore, the national income identity is still $Y = w_L L + w_H H$.