MRes Dissertation*

Creative Destruction in the development process

An application to East and West Germany

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1 Introduction

Countries differ greatly in their living standards and growth rates. Although many developed countries have experienced slowing firm dynamism and declining growth rates in recent decades, a catching up by developing and underdeveloped countries in the near future appears utopic. Often times, advantages in production efficiency for firms in developed countries serve as an important explanation of this fact.

The underlying causes for greater production efficiency in developed countries such as the United States range from greater managerial delegation efficiency (Akcigit, Alp, & Peters, 2021) and better human capital availability to fewer credit market and contractual frictions (Acemoglu, Aghion, & Zilibotti, 2006). Additionally, production efficiency is in itself a firm characteristic. Much of the recent literature on the topic of firm dynamics and growth has focused on the most developed countries, with a large focus on the United States, whereas mis-allocation and inefficiency analysis often takes developing countries into account more, such as India (e.g. Akcigit et al. (2021) or Hsieh and Klenow (2009)) or China (e.g. Hsieh and Klenow (2009)).

Cross-country comparisons through the lens of firm dynamics, on the other hand, are performed somewhat more sporadically[1] as it is often more difficult to come by comprehensive data. Bartelsman, Haltiwanger, and Scarpetta (2013) are one example of a model that captures cross-country differences.

Importantly, some approaches that explain productivity differences between countries may fall short of addressing the respective challenges of developing countries if they are based on patterns that prevail in developed countries. Firm, industry, and country character-

[1] This is only partly true, since in many studies the United States are used as a benchmark against which developing countries' efficiency is measured.

istics are often difficult to quantify and their relative importance might vary along the development process. While firms within very underdeveloped economies fail to adopt efficiency enhancing technology[2] or struggle to find capital[3], these problems are replaced with difficulties to find suitable managers in more developed countries. Ultimately, it is easy to imagine that very developed countries struggle with the search for new ideas or the adoption of intangible capital and yet depend on them to grow ever more.

These heterogeneities along the development process are essential when thinking about industrial policies or policy reforms within countries that ultimately aim at fostering growth.

A prominent example of a theory that captures differences in the relative importance of inefficiencies across countries is Acemoglu et al. (2006). They argue that creative destruction is more important in more advanced countries, whereas in developing countries the adoption of existing technologies is the main driver of growth. Then, growth in developing countries is slow due to market frictions and low capital availability that block businesses from adapting these existing technologies, rather than due to a lack of competition.

In this paper I build on that idea, using a Schumpeterian growth model with firm heterogeneity and cross-country spillovers from technology as proposed by Peters and Zilibotti (2021). It ranks countries on a "global productivity ladder" depending on the degree of creative destruction they experience. While the most advanced countries rely on innovation to create growth, countries that rank low on the productivity ladder are able to imitate existing technologies. The creative destruction events they do experience are

[2] A large strand of literature explains under-adaptation of efficient production technologies such as fertilizers in agriculture in developing countries through the lack of convincing insurance.

[3] For example, institutional settings that do not guarantee the enforcement of property rights seem to be a very poor environment for successful business start-ups and investments.

characterized by larger step sizes in innovation than in more developed countries.

I apply the model to the German economy, which is an interesting case for three reasons. First, being one of the largest and most influential economies in the Euro-Area and the world, with a per capita GDP of $\$50,794.95$ US dollars in 2021 (which according to the world bank amounts to more than 300% of the World average) and having the largest net export balance in the world, there are still productivity differences to the US. Germany lags behind the US in aggregate labour productivity growth (Broszeit, Laible, Fritsch, & Görg, 2019) and the adoption of new, especially IT related, software and capital (Bloom, Sadun, and Van Reenen (2012) find that European establishments increase their production efficiency after being acquired by US multinationals). While it is interesting and important to understand the differences between developed and developing countries, it is to some extent less obvious why productivity differs between equally developed countries. Yet, these differences are significant and persistent, even when controlling for many factors (Broszeit et al., 2019). Broszeit et al. (2019) find that one possible explanation for these productivity differences between Germany and the US are lower management scores that measure management quality in Germany[4]. Another explanation is proposed in this paper.

Second, within Germany a large discrepancy between the East and the West remains even more than thirty years after unification. While institutional settings do not differ significantly between the two areas, the living standard in the Western *Bundesländern* is markedly higher. Unemployment in the East was more than 35% higher than in the West in 2019 (6.4% vs. 4.7%) while average income in the East was around 89% of that in the West in 2018 (Martens & Gebauer, 2020). At the same time, consequences of de-

[4]Bloom et al. (2012) mention "tougher "people management" practices" by US firms.

mographic changes are felt more intensely in the East as young professionals and families move to Western conurbations. Differences in competitive behaviour might be able to explain these discrepancies partly.

Thirdly, the IT sector in Germany is the only sector that has not experienced a slow down in firm dynamism in recent decades. While the German government has supported entrepreneurship greatly, it appears that the IT sector profited from these policies over-proportionally. Entry may well be a large driver of productivity in this sector, whereas lower barriers to entry did not benefit other sectors in the same way. Following the theory proposed in this paper, the IT sector experiences relatively high rates of creative destruction but these are largely driven by high entry, rather than the efficiency of transformative firms. Non-IT sectors like manufacturing, on the other hand, have not experienced large entry rates and creative destruction is low because incumbent innovation is not fostered enough. For these reasons, sectors rely on policies that foster selection and increase the efficiency of transformative firms, rather than allowing subsistence firms to enter the market easily. I will discuss the case of Germany further in Section 3.

2 Literature

Firms are heterogeneous within countries but even more so across countries. A large strand of literature explores these heterogeneities within the United States, going off of the assumption that productivity differs between firms and that only those with productivity greater than a certain threshold stay active in the market, as proposed by Hopenhayn (1992). Melitz (2003) argue that another productivity threshold exists above which firms choose to operate not only domestically but in foreign markets as well. Among those firms that are able to operate internationally, a trade-off between the size of fixed and variable costs determines whether a firm does so through exports or foreign direct investments (Helpman, Melitz, & Yeaple, 2004). Wagner (2013) investigates the links between firm survival and international trade, looking at exporting firms, importing ones and those that engage in two-way trading. He finds a strong link between firm survival and imports, as well as firm survival and two-way trading, whereas exports do not influence the chances of survival in the case of Germany.

Restuccia and Rogerson (2008) prominently model establishment heterogeneity in the US and suggest that the resource allocation between such establishments might explain cross-country differences as well. Bartelsman et al. (2013) use heterogeneous distortions to match cross-country moments to the same end.

The relevance of creative destruction as a driver of firm competition and economic growth has been on the forefront of growth economics since the seminal work of Aghion and Howitt (1990). In their work, firms innovate on own products in order to increase their production efficiency. This research and development (R&D) activity causes growth because product quality increases, product variety rises and prices fall, since products become increasingly more developed and cheaper to produce. However, the incentives firms have to innovate depend on the expected rents from successful innovation. When the (Poisson) arrival rate of innovation is high, pay-offs from research are low because it is likely that a firms' products will be innovated on by another firm quickly, thus "stealing" rents. Among the most prominent Schumpeterian growth model is that of Klette and Kortum (2004), which includes the notion of firm heterogeneity and links the firm size distribution of a country to its rate of creative destruction and the within-country firm dynamics. Their model constitutes a main building block of the model presented in this paper.

Research on a decline of firm dynamism in developed countries, measured by lower reallocation rates, a decreasing skewness of the distribution of firm growth and lower entry rates, includes Decker, Haltiwanger, Jarmin, and Miranda (2016), Pugsley and Șahin (2019). De Ridder (2019) explains these trends through the use of intangible capital, arguing that firms that adopt cheap (because it is easily scalable) intangible capital well can undercut innovating entrants on the price dimension and deter innovation incentives that way. Another explanation for declining dynamism is given by Peters and Walsh (2021), who argue that slower population growth reduces creative destruction and firm entry, a theory that may well be suitable to explain differences in these variables between East and West Germany.

While firms in developed countries have incentives to innovate and increase their product efficiency, as well as quantity, this might be less true for developing countries. Instead, as Acemoglu et al. (2006) argue, market wedges and other distortions hinder economic growth in many underdeveloped countries to a much larger extent than a lack of competition. Because firms in underdeveloped countries are relatively easily able to adapt existing technologies and create growth through that channel, own innovation is less important. Thus, even though competition and selection in developing countries might be low, other distortions hinder growth more and should therefore be addressed by policies first. However, when a country approaches the end of a growth trajectory that was driven by adoption of technologies it must turn towards market-oriented policies, which support selection. Zilibotti (2017) investigates the case of China and develops a prediction for its further growth trajectory. Since the country was able to create substantial growth through industrialisation and adoption of technologies until 2011, it might find itself at a stage that requires a switch from adoption to innovation in order to sustain comparable growth rates[5].

Peters and Zilibotti (2021) abstract from labour and credit market distortions and analyse the importance of competition in developing countries. They argue that a large share of small firms in India together with a flat life-cycle growth imply that the rate of creative destruction must be much lower in India than the United States. More precisely, since entry and exit rates between both countries do not differ greatly, the reason why consistently small (and thus inefficient) firms persist in India must be that they are not replaced ("mopped up") by more productive firms, which would then in turn grow[6]. To quantify the effects described above, Peters and Zilibotti (2021) estimate entry costs, the innovation efficiency of transformative firms, and the share of subsistence firms in the US and India by matching the model to the entry rate, the share of small firms, and the extent of life-cycle growth. This analysis also determines the extent of creative destruction within both countries. Matching differences in aggregate productivity determines how much firms can profit from technology adoption, rather than innovation.

Using an entry rate of 8% for both countries, a value of 0.9 and 0.4 for the share of small firms for India and the United States, respectively, and a value of 1.1 (India) and 2 (US) for the life-cycle growth, they find that creative destruction is more than twice as big in the United States as it is in India. Additionally, only 16% of Indian firms have growth potential, whereas that share is almost 30% in the US. When comparing the structural parameters of the model, Peters and Zilibotti (2021) find that the discrepancies in difficulty of entry between India and the United States are less adverse than those in expansion efficiency of transformative firms. In other words, entry is less important than fostering the

[5] In general it is not obvious at what threshold such a switch is required.

[6] Additionally, in many countries small firms receive protection and financial support from the government, policies that might be greatly redirected in the light of this paper.

growth potential of firms. Counterfactual experiments where they set each of the three main Indian structural parameters to United States' levels reveal that a higher incumbent innovation efficiency would have the largest quantitative effect on creative destruction in India in that it would increase it close to 0.2, the same value that prevails in the United States and almost double of what it currently is in India. Adjusting barriers to entry to US levels or increasing the share of transformative firms would have much lower effects. The effects on aggregate productivity mirror this, in that greater innovation efficiency would increase productivity 8-fold, a much larger effect than can be obtained by changes in entry costs or a higher share of transformative firms.

Nevertheless, industrial policies that selectively support transformative firms by blocking some of the product-stealing that these companies experience would not increase welfare in India. This is because the disincentivizing effects on innovation activity of such policies outweigh the positive ones. Merely when the authors assume that transformative firms have a bigger step-size in innovating than do subsistence firms (upon entry) do they find a positive effect on income in India from targeted industrial policies.

3 The Case of Germany

Firm dynamism across almost all sectors in Germany has slowed down in recent years and innovation efficiency has declined (Naudé & Nagler, 2018). While Germany has created much of its economic growth and status in the world economy by being a large innovating country early in the 20th century and having a world leading position in the automobile industry or machine tools, it has missed out on leading positions in new fields such as nanotechnology, computing, 3D-printing, semiconductors, molecular biology or robotics, technology that is sometimes seen as part of the "fourth industrial revolution" (Naudé &

Nagler, 2018).

In light of these trends, policies that aimed at incentivizing start-ups and innovation activity (by entrants) by the German government included programs that facilitate access to capital and lower entry barriers (start-up costs) over the last decades. Equally, easier market exit has been in the focus of policy debate so that resources from inefficient firms could be allocated to more efficient ones (Bersch, De Monte, Hahn, Licht, & Stiftung, 2021). These measures are based on the assumption that firm dynamism and especially greater firm entry creates growth as it triggers larger innovative activity. However, this only holds true if entrant innovation is actually efficient, in which case it should be facilitated. If we follow the theory discussed in this paper, it is ex ante unclear whether new entrants are productive, i.e. have growth potential. If a large share of firms does not have growth potential after entry, inefficiencies are not optimally addressed through start-up policies. Although entry contributes to creative destruction, the effect of incumbent innovation is much larger. Other factors like increasing the efficiency of transformative producers is then a more effective policy tool than facilitated entry. This is supported by the findings of Bersch et al. (2021), who identify incumbent innovation in Germany as a main driver of aggregate labour productivity growth and especially so through within-firm productivity improvements. They also find allocative inefficiencies among German incumbent firms in most sectors (labour moving to less productive firms), which hamper productivity growth. This is also in line with Peters and Zilibotti (2021), who identify entry as less important than improving the efficiency of incumbent firms in India.

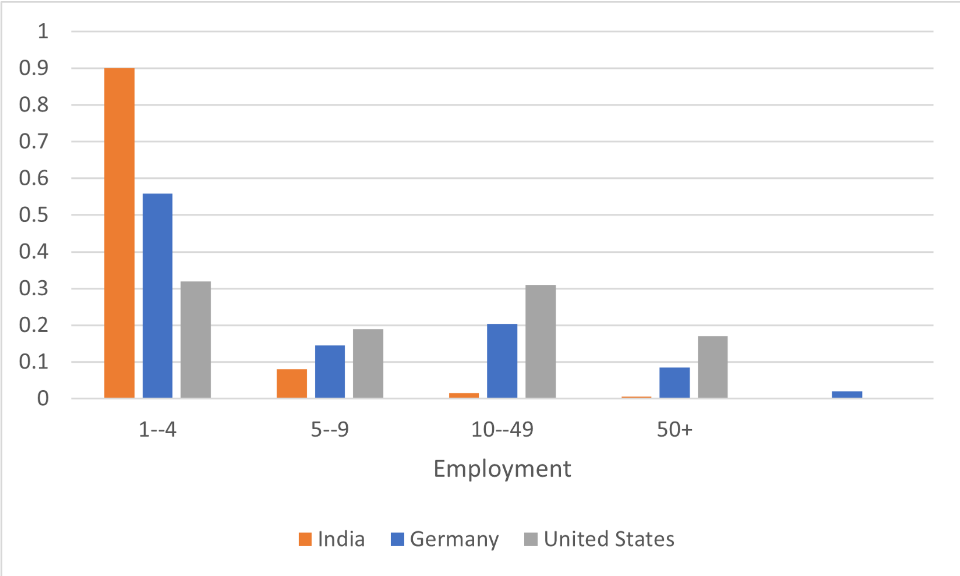
One sector that has not experienced a decline in dynamism in Germany is the IT sector, in which entry rates have been stable around $8-9\%$ between 2005-2019 (Bersch et al., 2021)[7]. Thus, at first glance, facilitated entry might have benefited the IT sector over-proportionally. Nevertheless, non-IT and low-tech sectors have long been a main driver of German economic growth. Jorgenson, Ho, and Stiroh (2008) suggest that the low-tech sector was also the main producer of economic growth in the US at the end of the last century because technology diffusion and adaptation are relatively "easy" growth engines[8].

In this light, "Entrepreneurship policy" (Bersch et al., 2021) might have focused on the high-tech sector too much and policies that meet the requirements of low-tech sectors are scarce. Equally, greater policy focus should be on increasing incumbent innovation rather than focusing on entry alone.

I now turn to the manufacturing sector, which the main analysis of this paper is based on. Like most industrialized countries, the German economy has experienced a structural transformation over past decades. However, the trend of a falling share of manufacturing in total output (value added) is less pronounced than in other developed countries (in 2017, 22.8% of German GDP stemmed from manufacturing, while it was only 16.9% in the world). In fact, since the 1990's, the contribution of German manufacturing to GDP has not declined (Bardt & Lichtblau, 2020). While the employment share in manufacturing has decreased especially in the East after unification, this does not hold true for the country as a whole, where the employment share in manufacturing has increased since 2006. Coupled with a higher average wage in manufacturing than all sectors as a whole, high productivity, and above-average export shares as well as R&D activity, the manufacturing sector in Germany is generally seen as a large driver for German economic

[7] The same is true for the region of Berlin.

[8] The extend to which this growth can be sustained is unclear in the context of this paper but technology adoption is possible for any economy (or sector) that has not reached the technology frontier yet.



Notes: The firm size distribution for India and the US stem from Peters and Zilibotti (2021). I have combined the employment sizes that are reported respectively.

Figure 1: Firm size distributions in manufacturing.

growth[9]. This is particularly interesting in light of the low entry rates of manufacturing firms that I discuss in the quantitative analysis.

Figure 1 shows the firm size distribution in manufacturing for India, Germany and the United States[10]. A clear picture emerges that places Germany between the US and India in that the share of small firms in Germany is relatively high, but larger size classes are still much bigger than the respective shares in India. A characteristic of the German economy is the importance of small and medium scale businesses, the so called *Mittelstand*, which is generally considered the "backbone" of the German manufacturing sector (Broszeit et al., 2019). The implications of this pattern will be analysed in Section 5.

[9]Bardt and Lichtblau (2020) lists this as one of the factors of the *Deutsche Geschäftsmodell*, German business model.

[10]The size classes reported vary between Germany and the US so that the classical declining shape of the distribution cannot be seen in this combined representation.

The East German economy experienced reforms that were aimed at privatizing firms to integrate them into a free market after unification. Many firms did not survive these first turbulent years, such that large entry of new establishments followed. Compared to the West, the Eastern Bundesländer had an average entry rate 1.6 times higher than in the West between 1991 and 2000, with a declining trend (from 1991 to 1992 the average establishment entry rate of the East was 2.6 times that of the West was , from 1999 to 2000 it was 1.1 times as big) (Grotz & Brixy, 2002). Firm growth and firm survival in the East were initially favoured as competition was low. At least since 2005 entry rates in the East fell below those in the West. It appears that after an initial surge in business dynamism in the East its productivity has slowed down and further catching up to the West was missed.

A tentative explanation for the regional differences might be found in the predominant sectors that are focused in both areas. However, Mertens and Müller (2020) find that Eastern firms are physically less productive than Western ones, rejecting the prominent "extended work-bench hypothesis". In Section 5, I analyse rates of creative destruction that provide further insight into differences between both areas.

4 Theory

4.1 The model

I use a model of creative destruction with endogenous firm dynamics, as presented by Peters and Zilibotti (2021). Countries interact through international spillovers only.

Within each country households bundle the final good as

$$\ln Y_t = \int_0^1 \ln y_{it} di \tag{1}$$

where each intermediate good y_{it} is produced using labor and with certain productivity q_{it}, i.e. $y_{it} = q_{it} l_{it}$. Profits of a monopolist that produces each product are given by

$$\pi_t = \frac{\mu - 1}{\mu} p_{it} y_{it} = \frac{\mu - 1}{\mu} Y_t$$

with μ being an exogenous mark-up and p_{it} being the price of good i. Total employment on each product is

$$l_i = \frac{y_{it}}{q_{it}} = \frac{1}{\mu} \frac{Y_t}{w_t}$$

which can be rearranged to yield aggregate output

$$Y_t = \mu L_{Pt} w_t = Q_t L_{Pt}$$

where $Q_t = exp(\int_{i=0}^{1} lnq_{it} di)$. Then, a firm's employment and its total sales can be derived in dependence of the number of products it produces, i.e.

$$l_f = n_f l_i = n_f \frac{1}{\mu} \frac{Y_t}{w_t} = n_f L_{Pt} \qquad \text{and} \quad py_f = n_f Y_t.$$

Creative destruction, or innovation, occurs when a firm increases the productivity of an existing good, it then takes over the production of that good from the current monopolist, who exits if she has no other products left in her portfolio. Creative destruction can stem from incumbents and entrants alike. The mass of entrants at any point in time is z. However, an entrant might only acquire one product upon entry and never innovate thereafter. This happens with probability $1 - \delta$ and such a firm is called *subsistence firm.* On the other hand, with probability δ upon entry a firm becomes a *transformative firm* and can increase its product portfolio at rate X in any following period. A transformative incumbent chooses its innovation rate optimally, as costs associated with innovation are

$$c(X, n) = \frac{1}{\phi_x} X^{\zeta} n^{1-\zeta} = \frac{1}{\phi_x} x^{\zeta} n,$$

where $x = \frac{X}{n}$ is the innovation intensity and $\zeta > 1$. The innovation efficiency of incumbent firms ϕ_x in this expression is one of the structural parameters of this model and is estimated in Section 5.

The value function of a transformative firm, V_t^T, solves the following HJB, which incorporates the firm's flow profits, the possibility that a firm might lose products to other firms (at the flow rate $n\tau_t$), and the option value of expansion (which occurs at rate nx):

$$r_t V_t^T(n) - \dot{V}_t^T(n) = n\pi_t - n\tau_t[V_t^T(n) - V_t^T(n-1)] + \max_x \{nx[V_t^T(n+1) - v_t^T(n)] - \frac{1}{\phi_x} x^\zeta n w_t\}. \tag{2}$$

The value function takes the solution $V_t^T(n) = v_t^T n$ along the BGP, where

$$v_t^T = \frac{\pi_t + (\zeta - 1)\frac{1}{\phi_x} x^\zeta w_t}{\rho + \tau} \tag{3}$$

is the value of each product a transformative firm produces. It decreases in the rate of creative destruction τ as a greater risk of losing a product to another innovating firm lowers the value of the firm that possesses it. The optimal rate of incumbent innovation is

$$x = \left(\frac{v_t^T}{w_t} \frac{\phi_x}{\zeta}\right)^{\frac{1}{\zeta - 1}} \tag{4}$$

and incorporates the value of a product relative to the equilibrium wage. The higher that ratio, the more incentive a transformative firm has to innovate.

The value of a subsistence firm in turn is given by

$$v_t^S = \frac{\pi_t}{\rho + \tau}. \tag{5}$$

This expression differs from equation (3) only insofar as the cost of innovation for a subsistence firm is arbitrarily large, i.e. $\phi_x \to 0$. Thus, innovation is never optimal for a subsistence firm. The difference in the value of a transformative and a subsistence firm does not incorporate the social value of innovation, which would additionally increase the gap between both.

Firm entry is subject to the linear entry technology

$$\varphi(z) = \frac{1}{\phi_z} z^{\chi}, \tag{6}$$

where $\chi > 1$ assures decreasing returns to scale to entry and $\varphi(z)$ are the workers an entrant needs to hire. The parameter ϕ_z is the inverse of entry costs, another structural parameter of the model. Since firms cannot anticipate whether they will become a transformative firm after entry, the free entry condition equates the cost of entry to the expected value of a firm, i.e.[11]

$$\frac{1}{\phi_z} z^{\chi} w_t = \delta v_t^T + (1-\delta) v_t^S = \frac{\pi_t + \delta(\zeta - 1)\frac{1}{\phi_x} x^{\zeta} w_t}{\rho + \tau}. \tag{7}$$

Finally, creative destruction τ is given by

$$\tau = z + \sigma^T x. \tag{8}$$

That is, the flow of entry z and the innovation rate x determine its size because any entering firm and every innovation by an incumbent replace the production by a monopolist. The presence of the share of products owned by transformative firms, σ^T, in the above expression indicates that transformative firms innovate proportionally to the products they have a monopoly on. Additionally, creative destruction increases in both, the entry rate and innovation rate of transformative firms. However, the effect from incumbent innovation is larger as the share of products owned by incumbents increases with incumbent innovation as well. The share of products owned by transformative firms is given by

$$\sigma^T = 1 - F^S = 1 - \frac{(1-\delta)z}{\tau}, \tag{9}$$

[11] This expression is equal to the value of a transformative firm, discounted by the probability of becoming such a firm upon entry.

where F^S is the stationary mass of subsistence firms which is given by the ratio of subsistence entrants, $(1-\delta)z$, to subsistence exits, τ (since these firms have only one product an event of creative destruction will force them out of the market). Equation (9) holds because each subsistence firm produces only one product, so that the share of products produced by transformative firms is $1-F^S$ (the product space is normalized to 1). Inserting equation (9) into equation (8) yields

$$\begin{aligned}\tau &= z + \left(1 - \frac{(1-\delta)z}{\tau}\right)x \\ &= \frac{z+x}{2} + \sqrt{\frac{(z+x)^2}{4} - (1-\delta)zx}.\end{aligned} \tag{10}$$

Labor market clearing is given by

$$\begin{aligned}1 &= L^P + L^E + L^R \\ &= L^P + z\varphi(z) + \frac{1}{\phi_x}x^\zeta\sigma^T \\ &= L^P + z^{1+\chi}\frac{1}{\phi_z} + \frac{1}{\phi_x}x^\zeta\left(1 - \frac{(1-\delta)z}{\tau}\right),\end{aligned} \tag{11}$$

where the superscripts to L stand for production, entrants, and research workers, respectively. The second line shows explicitly the labour demand of the latter two sectors. The aggregate labour force is 1.

The balanced growth path within a country is then characterized by a constant innovation rate x, entry flow rate z, creative destruction τ and share of production workers L^P. The value functions v_t^S and v_t^T grow at the constant productivity growth rate g. The free entry condition (7), incumbent optimality (4), labour market clearing (11), creative destruction (16), and value functions ((5) and (3)) pin down the equilibrium parameters.

Aggregate Growth and Distance to Frontier are closely linked to each other. The further away a country is from the economic frontier the more easily it can grow in the sense that the step size of innovation, γ, is bigger. This step size, which increases the product specific productivity q_i, is determined as

$$\gamma_{ct} = 1 + (Q_{Ft}/Q_{ct})^{\kappa},$$

where the parameter $\kappa > 0$ captures the fact that a country c whose aggregate productivity Q_c is far from that of the frontier economy (Q_F) has a larger step size than an economy that is closer to the frontier (in terms of aggregate productivity). The "speed of convergence" is then determined by the size of κ, as countries with a large productivity gap to the frontier can profit from their relative backwardness better when κ is large (as that increases the step size of innovation). Productivity growth in a country evolves as

$$g_{ct} = \frac{\dot{Q}_{ct}}{Q_{ct}} = \ln(\gamma_{ct})\tau_c = \ln\left(1 + (Q_{Ft}/Q_{ct})^{\kappa}\right)\tau_c \tag{12}$$

Since this relation holds for any economy, the growth rate of the frontier is simply given by $g_F = \ln(2)\tau_F$, or $\tau_F = \frac{g_F}{\ln(2)}$, which is by construction the highest possible rate of creative destruction. Inserting the frontier growth rate into equation (12) yields

$$Q_c = \left(exp\left(\frac{ln(2)\tau_F}{\tau_c}\right) - 1\right)^{-1/\kappa} Q_F.$$

The rate of creative destruction of each country determines its rank on the global productivity ladder.

4.2 Firm Dynamics

The theory discussed above can be estimated through three moments. First, the firm entry rate is directly affected by the rate of creative destruction because entering firms replace monopolists in the production of the good they improve on to enter the market. Second, the share of small firms is indicative for the extent to which inefficient producers are tolerated in the market even though they should be replaced ("mopped up") in a more efficient system. Third, the speed of life-cycle growth indicates the growth potential of firms after entry, which depends on the probability that a firm has growth potential and its innovation efficiency.

The entry rate is given by the ratio of entering firms to total firms, which in turn consist of subsistence firms and transformative ones. The mass of the former is given in equation (9) and the mass of the latter can be derived as $F^T = -\frac{\delta z}{x}\ln(1-\frac{x}{\tau})$. Then

$$\begin{aligned} er &= \frac{x}{F^T + F^S} \\ &= \frac{\tau}{1-\delta(1+\frac{\tau}{x}\ln(1-\frac{x}{\tau}))} \end{aligned} \tag{13}$$

The share of small firms, which is proxied by those that produce only one product, can be derived as

$$\vartheta(1) = \frac{1}{1-\delta(1+\frac{\tau}{x}\ln(1-\frac{x}{\tau}))}. \tag{14}$$

Finally, the firm life-cycle growth is given by

$$\begin{aligned} E[n|a] &= \lambda^{Sub}(a) + (1-\lambda^{Sub}(a))E^T[n|a] \\ &= 1 + (1-\lambda^{Sub}(a))\frac{x}{\tau - x}(1-e^{-(\tau-x)a}), \end{aligned} \tag{15}$$

where

$$\lambda^{Sub}(a) = \left(1 + \frac{\delta}{1-\delta}\frac{(\tau - x)}{\tau e^{-xa} - xe^{-\tau a}}\right)^{-1}$$

is the share of subsistence firms of age a and

$$E^T[n|a] = 1 + \frac{x}{(\tau - x)}(1-e^{-(\tau-x)a})$$

is the conditional size of transformative firms. Equation (15) expresses the size of the average firm in the market, dependent on age a: subsistence firms only have one product and transformative firms have $E^T[n|a]$ products. The share of subsistence firms depends negatively on age because the probability of their survival is low. The size of a transformative firm increases with age, however, the larger x is relative to τ the bigger firms will be (and the lower $\vartheta(1)$ will be). Lastly, equation (13) can be expressed as

$$er = \tau\vartheta(1). \tag{16}$$

Large entry rates increase innovation per definition, as firms always enter with a new product. If the share of small firms does not increase over-proportionally, that is, as long as a sufficient share of firms has growth potential and leaves the group of small firms, creative destruction will rise.

5 Quantitative Analysis

In order to estimate the structural parameters of the model, ϕ_z, ϕ_x, and δ, I target the three moments derived in Section 4 in the German firm-level data. These are the firm entry-rate, the share of small firms[12] and the extend of life-cycle growth, which is the employment growth of entering firms after 5 years[13]. I adopt the calibration of external parameters $\rho = 0.05$, $g_Q^F = 0.02$, $\chi = 0.1$ from Peters and Zilibotti (2021) and use a quadratic cost function.

The moments, given by equations (10), (13), (14), and (15) pin down the model parameters z, x, τ, and δ. Equations (11) and (4) yield the structural parameters ϕ_z and ϕ_x.

[12] These are firms that only produce one good, whereas in the data I take the share of firms with less than 4 employees.

[13] Peters and Zilibotti (2021) use the growth after 10 years, this is not available in the data set I use.

Data

The *Statistisches Bundesamt* (Federal Statistical Office) collects and reports data on firm birth, survival and employment size, among others, in the Business register system, *Unternehmensregister-System (URS)*. The variables are reported by sector according to the "Klassifikation der Wirtschaftszweige, Ausgabe 2008" (WZ 2008) and are available for the years 2018-2020.

For the *manufacturing* sector, I match the model to an entry rate of 4.2%. The number of enterprises within each sector is reported by employee size classes, where the sizes are 0, $1-4$, $5-9$, and 10 or more employees. I calculate the share of the first two groups in manufacturing and take the average of the three resulting shares from 2018-2020. The share of small firms is then 0.56. Firm survival is reported only for firms that were established up to five years ago. The employees conditional on survival are again reported for the years $2018-2020$ and life-cycle growth in that period is 1.58.
Although Germany is one of the most advanced countries in the world, differences in productivity to the United States remain. Following the theory proposed above, creative destruction should be lower in Germany than in the US if it is the case that a lack of innovative activity contributes to the productivity differences between both countries. For the same reason, creative destruction in Germany should be significantly larger than in India where a large share of firms with no growth potential is not replaced ("mopped up") by more efficient ones. Nevertheless, the entry rate in manufacturing firms in Germany is notably smaller than the corresponding values in the US and India, for which Peters

	Moments				Structural Parameters				Equilibrium Outcomes		
	er	$\vartheta(1)$	$E[n\|10]$	Q	δ	ϕ_x	ϕ_z	κ	z	x	τ
US	0.08	0.4	2	1	0.29	0.28	0.92	0.42	0.0015	0.2	0.2
India	0.08	0.9	1.1	0.125	0.162	0.061	0.6	0.42	0.066	0.061	0.09
	er	$\vartheta(1)$	$E[n\|5]$	Q	δ	ϕ_x	ϕ_z	κ	z	x	τ
Germany	0.08	0.4	1.58	0.9	0.52	0.28	0.83	-	0.009	0.195	0.2
Germany	0.058	0.4	1.58	0.9	0.937	0.16	0.58	3.2	0.015	0.13	0.145

Notes: The values for the US and India stem from my own implementation of Peters and Zilibotti (2021). The results align, except for ϕ_z in the US, which is 0.706 in their study. The values for Germany depict the situation in the early 2000's.

Table 1: Model Parameters.

and Zilibotti (2021) use a value of 8% for both. I report the results of matching the three data moments of India and the US to the model in the first two rows of Table 1. Creative destruction in the US is more than twice as big as it is in India. However, an entry rate of 8% in manufacturing seems quite high, especially for the case of India, for which Akcigit et al. (2021) report a value of only 5.6%. Creative destruction would be 0.062 in India when the entry rate is low.

The combination of a small entry rate and relatively large share of small firms place creative destruction in the German manufacturing sector at 0.077, which is dauntingly low when compared to India and the US. Firm entry - if not the most efficient one - is one driver of creative destruction (see equation (10)) and with a relatively low entry rate the latter is necessarily low, even though the growth potential of German manufacturing firms is very high, even compared to the US.

A decline in business dynamism over recent years contributes to this result. Entry rates reported by Bersch et al. (2021) from 2005-2019 evidently decline over time, even though manufacturing and IT exhibit the most stable rates. Wagner (2013) report exit rates for the years 2001-2004, which are notably higher than the values I have used here. Indeed, a simply average between the East (5 Bundesländer with an average entry rate of 10.07) and West (11 Bundesländer with an entry rate of 7.69) yields an entry rate in manufacturing of around 8% for the country as a whole. Although the firm size distribution in the model is stationary, entry and exit rates are not the same in the data. Bersch et al. (2021) show that entry rates in Germany were higher than exit rates until at least 2011, while the two rates are close to equal for manufacturing. The manufacturing entry and exit rates reported by Bersch et al. (2021) from 2005 onwards are between 4% and 5%. Also reported by Wagner (2013), the share of firms that produce only one product is roughly 41% from 2001-2004. I solve the model for two specifications of the entry rate in order to capture dynamism in the early 2000's. Table 1, line 3 reports results for an entry rate of 8%, which places Germany at the same rate of creative destruction as the US. The more conservative estimate of an entry rate of 5.8% is shown in line 4. Striking in both cases is the overly large share of transformative firms, represented by δ. This parameter is driven by the large life-cycle growth. Firms that survive 5 years grow by almost 60% relative to their first year, whereas even in the United States that rate is only 50%. As the innovation rate x in both specifications of the entry rate is relatively high compared to creative destruction, it is clear that a large share of firms must be transformative in order to create fast firm growth.

As shown above, a decrease in entry rates in manufacturing combined with an increase in the share of small firms from around 40% to 58% have contributed to a prominent drop in creative destruction from above 0.14 to 0.077 in the last 20 years.

The speed of adoption κ is very high for the case of Germany, assuming a productivity gap of around 10% between the US and Germany. This must hold true because large differences in creative destruction coupled with relatively low differences in productivity (compared to those that persist between the US and India) indicate that adopting existing technologies is a large growth channel for Germany. Increasing creative destruction would then do relatively little to decline productivity differences. Remember that the step size of innovation depends on the differences in productivity between a country and the technological frontier, as well as on the ease of adoption. Intuitively Germany is already very close to the economic frontier so that the step size of innovation is much lower than it is in less developed countries like India. In order to catch up to the economic frontier, large increases in creative destruction are needed.

East-West differences in productivity remain over thirty years after unification. Grotz and Brixy (2002) report that especially *East German* firms that were founded during the restructuring of the country were able to survive and grow rapidly. Entry rates after unification were higher in the East than in the West. Wagner (2013) reports firm exit

	Creative destruction				
	2001	2002	2003	2004	2019
East	0.24	0.28	0.24	0.22	0.054
West	0.23	0.21	0.187	0.158	0.063

Notes: Reported rates of creative destruction reflect dynamics in the manufacturing sector.

Table 2: Creative destruction in the East and West of Germany

rates and the share of firms with only one product for West and East Germany for the years 2001-2004 in the manufacturing sector. Although these moments are not sufficient to solve for all model parameters, equation (16) allows to calculate creative destruction for both areas. The results are shown in Table 2. Interestingly, creative destruction is higher in the East in all years. This fits neatly into the theory proposed in this paper. Since many Eastern enterprises formerly run by the State could not survive in a free market, large exit and entry rates followed. New firms were able to occupy market shares and grow quickly, which created overall high rates of creative destruction. Nevertheless, the rates of creative destruction shown here should be interpreted as an upper bound at best, since the entry rates they are based on are relatively large. Additionally, this trend does not continue today as West German firms outperform those in the East in growth potential and survival chances. A clear decline in creative destruction over the years for both regions is evident. At least from 2005 onwards, entry rates in manufacturing in the East decreased drastically, by as much as 50%. The decline in Western States is less pronounced and entry rates are on average higher. In 2019, the entry rate in manufacturing in the East is around 2.9%, whereas it is close to 3.5% in the West (Bersch et al., 2021). The share of small firms in the East is 0.54 and that in the West is 0.56. Creative destruction for these moments is reported in the last column of Table 2.

Assuming aggregate productivity to evolve as[14]

$$\frac{Q_{East}}{Q_{West}} = \left(\frac{exp\left(\frac{g_Q^F}{\tau_{East}}\right) - 1}{exp\left(\frac{g_Q^F}{\tau_{West}}\right) - 1} \right)^{-1/\kappa}$$

and that East German manufacturing is about 8% below that of West Germany in revenue productivity (Mertens & Müller, 2020), κ turns out to be high, with a value of 2. This expresses the fact that adoption is very fast and a lot of innovative activity is necessary to decrease the gap in productivity further.

[14] For this exercise I use a growth rate of 1% for the West, i.e. the "technology frontier within Germany".

Lastly, different sectors experience very different firm dynamics, which likely leads to different rates of creative destruction. Bersch et al. (2021) find the IT sector and the region of Berlin alone to be excepted from a decline in business dynamics, as both have not experienced declining entry rates to the same extent as other industries and regions. Nevertheless, the share of small firms in the IT sector is very high as well, at around 80%. With this in mind, I expect to find a larger value of creative destruction for the IT sector compared to manufacturing but for that rate to be largely driven by firm entry, rather than incumbent innovation. Indeed, creative destruction in the IT sector is 0.135. Where creative destruction in manufacturing is quite low (0.077) due to very low entry rates, the IT sector was able to create innovation, even if most of it is accounted for by firm entry rather than incumbent innovation. Even though Bersch et al. (2021) find a higher contribution of incumbent firms to aggregate labour productivity growth, the IT sector does not confirm this.

5.1 Further Analysis

Peters and Zilibotti (2021) use moments from manufacturing data to match the model. I have done the same for the case of Germany in the previous section. In order to test the theory further, I conduct the same analysis for *all sectors* here.

From the URS, I average the birth rate for all sectors in each given year and then again average the resulting entry rate of all three years. This way an entry rate of 8.1% for the case of Germany emerges. Interestingly, this is very close to the entry rates for India and the United States in Peters and Zilibotti (2021) (reported in Table 1). It is noteworthy that the entry rate for manufacturing is among the lowest of all sectors in Germany, which drives the results in the previous section. Bersch et al. (2021), on the other hand, report an average entry rate for all German firms of around 4%, as entry and exit have drastically decreased in all German states between 2005-2019. The share of businesses with under

	Moments			Structural Parameters			Equilibrium Outcomes		
	er	$\vartheta(1)$	$E[n\|5]$	δ	ϕ_x	ϕ_z	z	x	τ
Germany	0.081	0.45	1.4	0.394	0.233	0.818	0.0079	0.1768	0.18

Notes: Since Peters and Zilibotti (2021) do only provide an analysis for the manufacturing sector, I neglect κ and a productivity analysis here.

Table 3: Model Parameters for all sectors.

4 employees in Germany is given by 0.45. Lastly, the average increase in employment size between firms at entry compared to those that survived for five years is 40%, i.e. $E[n|5] = 1.4$. Life-cycle growth is depicted in Figure 2. Evidently, manufacturing and especially IT firms grow substantially faster than the average German firm. The results of matching the model to represent an entry rate of 8.1%, a share of small firms of 45%, and a life-cycle growth of 1.4 are shown in Table 3.

6 Policy implications

It is indicative that in Germany an increased ease of firm entry appears to have favoured mainly the IT sector. Although entry rates in manufacturing are also relatively stable when compared to other sectors, their levels are the lowest out of all industries. This holds true for high-tech as well as low-tech manufacturing, where the latter is constantly somewhat above the former (Bersch et al., 2021). I have found creative destruction to have declined drastically in the manufacturing sector in the last 20 years, whereas creative destruction in the IT sector is markedly higher. Nevertheless, creative destruction in the

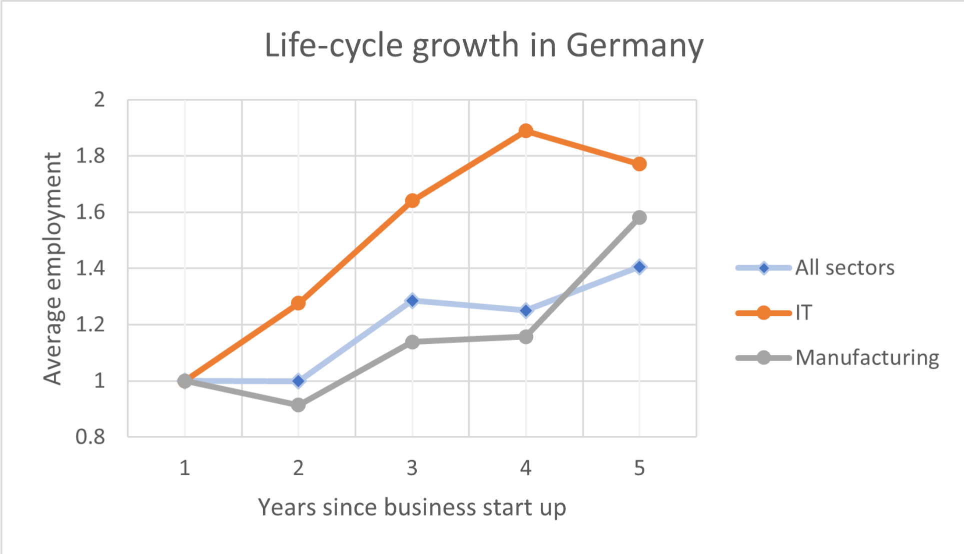


Figure 2: Life-cycle growth profile for selected industries.

IT sector is driven largely by entrants, which is less efficient than incumbent innovation. In manufacturing, incumbent innovation is a relatively big part of creative destruction. Additionally, in the face of slowing firm dynamism in almost all industries, it becomes increasingly important to foster growth through increases in incumbent innovation. Industrial policies in themselves, albeit often times criticised for being somewhat arbitrary, can be beneficial if they focus on providing sensible guidance and create incentives within regulatory frameworks (Bardt & Lichtblau, 2020). Start-up policies provide such incentives but might also lead to inefficient allocations, when firms enter the market that have no growth potential. Especially if start-up policies cannot increase business dynamism because other factors lower entry rates (for example demographic changes), it becomes increasingly important to further increase innovation activity and the efficiency of transformative firms and to not focus on entry-policies overly.

The OECD recommends "a level playing field" between incumbent firms and entrants, so that the most efficient firms enter and remain in the market. In that light, policies that facilitate market exit appear productive in order to free up resources from inefficient businesses.

Fostering knowledge through education is another important factor that is needed in order to create future innovation. Collaborations between universities and firms (OECD, 2015) as well as eased labour mobility can contribute to greater efficiency in incumbent firms.

7 Conclusion

I have used a model of creative destruction with heterogeneous firms and international knowledge-spillovers to capture the differences in creative destruction that prevail even between two of the most developed countries in the world. While Germany has experienced high firm entry rates and creative destruction in the early 2000's, declining dynamism has lead to a decrease in innovative activity. Decreased firm entry and an increase in the share of small firms cause these developments.

Especially the manufacturing sector is subject to worrying developments, whereas the IT sector appears to have benefited from start-up policies by the government. Nevertheless, creative destruction in IT is driven by firm entry a lot, when incumbent innovation efficiency is a more effective productivity enhancer.

The Germany economy is characterized by a large focus on the so called *"Mittelstand"*, which is small and medium scale businesses. These establishments are prominently focused in the policy debate but their innovation efficiency is not promoted sufficiently with start-up policies. Another idiosyncrasy of the German manufacturing and especially IT sector is a steep life-cycle growth profile, that is, firms grow a lot if they survive for five years after their entry into the market. It is difficult to combine the existence of many small firms with a relatively steep life-cycle profile, as is the case in almost all configurations I have shown in this paper. Only a large share of transformative firms can explain this feature. Additionally, firms that enter the market with under two employees (which is the case for many entering firms) may double their size after five years but still remain in the smallest size category of the model. In future research, better data availability should help to create a life-cycle growth profile that can depict firm size after more than five years.

Productivity differences between East and West Germany can be partly explained through higher rates of creative destruction in the West. While the Eastern *Bundesländer* experiences large firm entry rates after unification and around the turn of the century, these slowed down in the early 2000's and more drastically so than in the West. The fact that creative destruction in both areas is mostly created through entry rather than incumbent innovation signifies that policy advice that applies to the country as a whole is even more indispensable in the East, where entry rates decline fast. Policies that increase incumbent innovation by allowing efficient allocations of resources (for example, through facilitated exit) and do not focus on start-up policies overly are warranted.

Lastly, as Germany is already relatively close to the economic frontier, large increases in creative destruction are needed to produce further convergence. This is the case because an event of creative destruction creates lower quality improvements than it would in the case of a country that is far from the economic frontier.

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