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Product Diversification and Labor Productivity Dispersion in German Manufacturing Industries

René Söllner*

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Abstract

Empirical research has shown tremendous productivity differences, even within narrowly defined industries. A great host of studies is explainsing this productivity disparity by factors such as idiosyncratic technology shocks, input price differences, management skills, or international trade. Although these explanations are undoubtedly important, the current paper suggests that product diversification strategies of firms can also play an important role. Using a matched producer-product panel dataset of German manufacturing industries over the period 2003-2006, we find that the average degree of product diversification across industry establishments is positively related to within-industry labor productivity dispersion.

JEL classification: L11, L22, L25
Keywords: Product Diversification, Productivity, Industrial Dynamics

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1 Introduction

Micro-level data on the distribution of productivity and the evolution of productivity growth show persistent productivity differentials across firms, even within narrowly defined industries (see Bartelsman and Doms, 2000; for an overview). Salter (1960), analyzing the dispersion of labor productivity among plants producing pig-iron, for instance, finds that the best-practice pig-iron facility produced twice as many tons per labor-hour as the industry average. Criscuolo et al. (2003), performing similar calculations for UK manufacturing, show that the productivity at the 90^{th}percentile of the productivity distribution is over five times larger than the productivity at the 10^{th} percentile. The persistence of productivity differentials is puzzling and gives rise to a number of questions since classical economic theory rather suggests that poorly performing firms operating in workable markets should not be capable of survival. As a consequence, productivity dispersion is expected to decrease over time.

Theoretical models of industry dynamics that explain firm heterogeneity and generate complex patterns of firm productivity distribution over time can be found in the literature. The Jovanovic (1982) model of industry evolution assumes profit maximizing firms endowed with time-invariant efficiency levels. Through a process of selection, less productive firms recognize that they are never going to be profitable and exit the market. Since efficient firms survive while inefficient ones fail, the average efficiency of the survivors improves from period to period. Ericson and Pakes (1995) develop a model that accounts for many of the phenomena observable in firm-level datasets. The model assumes firms investing in R&D in order to enhance their capability to earn profits. Due to idiosyncratic shocks, the outcome of the investment is uncertain. As a consequence, very productive firms can even obtain efficiency losses. In contrast to inefficient firms, however, very productive businesses can immediately respond to negative external shocks making them both larger in size and output in the long-run.

Even though theoretical models generating persistent productivity dispersion have some appeal, empirical investigation may provide a more compelling way to describe what is observed in the data. There has definitely been progress in explaining the reasons why productivity levels are so different across businesses, but still, some influences have not yet been discussed. In particular, the role played by product diversification strategies of firms has completely been neglected by empirical economists so far. In this respect, our study makes important contributions to the existing literature. First, to the best of our knowledge, there is no previous study exploring a relationship between product diversification and productivity disparity using a micro-level dataset on German manufacturing industries. Second, by exploiting the panel structure of the data, to some extent, we overcome the limitations of related studies that solely rely on cross-sectional analysis (e.g., Syverson, 2004b). The results of this paper can shortly be summarized. We find that the aggregate degree of product diversification can be regarded as one of the central factors explaining productivity heterogeneity of firms within narrowly defined industries.

The remainder of this paper is structured as follows. In the next section, we review the literature that discusses various sources of within-industry productivity dispersion. Section 3 specifies the data used and we refer to the underlying methodology. The results of the empirical analysis are reported in Section 4. Section 5 concludes.

2 Related Literature

2.1 Determinants of Productivity Dispersion

Technology related factors. Among the various explanations for the existence of productivity differentials, the impact of innovation is by far the most discussed in the literature. Nelson (1981) emphasizes that differences among firms in access to and knowledge about new technologies cause cross-sectional productivity dispersion. In his view, firms often make wrong bets about new technologies. Since imitation is costly and time consuming technological advance yields disproportionately high returns to successful innovators. In a related study, Nelson (1991) stresses the importance of reorganization in order to transform new technology into productivity gains. Accordingly, organizational differences, in particular differences in the ability to generate and gain innovation, can be considered to be sources for durable productivity dispersion across firms. Similar arguments can be found in a model by Caselli (1999), where productivity heterogeneity is generated through differentials in the rate of technology adaptation. The relationship between R&D investment patterns, technological shocks and productivity at the micro level has been proven in a number of empirical studies (see Lichtenberg and Siegel, 1991; Hall and Mairesse, 1995; Dunne, 1994; among others).

Management and the quality of the workforce. Besides technology related factors, management skills and human capital may be important factors behind productivity heterogeneity (Bartelsman and Doms, 2000). Bloom and Van Reenen (2007) collect data about managerial practices for a sample of 732 medium-sized manufacturing firms in the United States, the United Kingdom, France, and Germany. Their results show that management quality accounts for around 33 per cent of inter-quartile differences in productivity. Womack et al. (1990) and Oliver et al. (1996) compare the quality and productivity of firms in the automotive industry. They argue that performance variations can be traced back to management practices and the adoption of lean-thinking principles. Abowd et al. (1999), Haltiwanger et al. (1999), and Haskel et al. (2005) investigate the relation between productivity and worker skills. All of them find that highly productive firms are more likely to have better skilled workers.

Market size, international trade and competition. The international involvement of a sector and market size effects have recently been studied as drivers behind within-industry dynamics. Building on the dynamic industry model to monopolistic competition by Hopenhayn (1992), Melitz (2003) theoretically examines the influence of international trade on the reallocation of market shares. The model shows how trade exposure induces more productive firms to export, while forcing the least productive ones to exit. Both the exit of less productive and the additional exports gained by productive firms reallocate market shares towards the efficient firms and contribute to an aggregate productivity increase. The model of Melitz (2003) implies lower within-industry productivity dispersion for sectors with intensified international involvement. A number of empirical studies disclose superior characteristics of exporting firms relative to those merely producing for domestic markets (Bernard and Jensen, 1997; Richardson and Rindal, 1995; Bernard and Wagner, 2001). Note that the causality between productivity and exporting could run both ways: One the one hand, high productivity firms might be more likely to overcome barriers to exporting than less productive firms. On the other hand, due to their exposure to foreign competitors, exporters may benefit from learning about new production technologies, and therefore attain higher productivity levels.[1] Based on the dynamic industry model of Melitz (2003), Melitz and Ottaviano (2008) analyze the effect of market size on the toughness of competition. Similar to Asplund and Nocke (2006), the model predicts intensified competition and, consequently, less dispersion of within-industry productivity for larger markets. This result is due to the fact that an increase in market size induces prices to fall. For some inefficient firms the profit margins then become

[1] Bernard and Jensen (1999) stress that productivity causes exporting and not *vice versa*.

so small that they decide to exit. A general impact of competitive pressure has also been recognized by Oulton (1998). He argues that differences between sectors in the extent of productivity dispersion can be attributed to varying degrees of competition. Since imperfect competition permits inefficiencies to persist, less competitive sectors have significant higher productivity dispersions.

Regulation and market intervention policies. Olley and Pakes (1996) emphasize the fact that regulatory policy affects productivity heterogeneity. Their case study of the U.S. telecommunication equipment industry shows that deregulation influences the choices of innovative activities, and the input and output volumes of producers and potential entrants. Reduced entry barriers due to deregulation policy encourage new firms to step into the market, and force inefficient firms to exit. As a result, an increase in aggregate productivity and a decrease of productivity dispersion after deregulation is observable. Similar findings are obtained by Arnold et al. (2008). Using cross-country firm-level data the authors show that regulation amplifies the productivity dispersion by hampering the allocation of resources towards the most dynamic and efficient firms. Arnold et al. (2008) also point out that deregulation does not immediately lead to lower dispersion. Since predominantly efficient firms at the top of the productivity distribution benefit from deregulation, during a transition phase, productivity can even become more dispersed. This is due to the fact that it takes some time to drive low performers out of the market. Other market intervention policies such as R&D subsidies can have similar effects. On the one hand, if subsidies encourage potential entrants to enter, more intensified competition will tend to decrease the productivity dispersion. One the other hand, if predominantly incumbent firms receive subsidies some relatively inefficient producer are enabled to remain in the market, while potential entrants will be deterred from entry as a consequence of the increased number of competitors.

Product diversification and demand-side factors. Most of the studies previously examined highlight the impact of supply-side factors on the productivity dispersion of industries, while studies investigating the demand-side as a source for persistent productivity heterogeneity are rather underrepresented. A remarkable exception is a study by Syverson (2004a) proposing that demand-side features also play a role in creating productivity variation within narrowly defined industries. The paper formalizes a theoretical model that incorporates consumers choosing among differentiated products sold by suppliers being heterogeneous with respect to their production costs. The model predicts that markets with higher spatial demand density (i.e., higher demand per unit area), and therefore higher density of producers, exhibit less productivity dispersion than low demand density markets. In fact, using data from the U.S. ready-mixed concrete industry, Syverson (2004a) shows that geographic substitution barriers can partly explain a persistent within-industry productivity dispersion. In addition, Syverson (2004b) theoretically and empirically investigates how output market segmentation (respectively product diversification) affects the productivity disparity within industries. The link between output market segmentation and an industry's productivity dispersion is assumed to be as follows. Suppose perfect homogeneity of outputs in an industry, then the firm that produces at lowest costs (i.e., with highest productivity) attracts the entire demand. However, perfect homogeneity of industry outputs (products) typically does not exist in reality. Physical product diversification in response to diverse consumer preferences leads to output market segmentation. This output market segmentation decreases the competition-driven selection process and allows less productive firms to survive, which results in a persistent within-industry productivity dispersion.

Sunk entry costs and fixed operating costs. Although Syverson (2004b) mainly focuses on the influence of output market segmentation on productivity disparity, his theoretical model and empirical analysis also incorporates other influential factors relating to the productivity distribution. In the spirit of Hopenhayn (1992), he discusses the idea that both sunk entry costs and fixed operating costs impinge on the critical productivity cutoff level,[2] and therefore on the moments of the industry productivity distribution. Sunk costs act as entry barriers that allow incumbent firms to charge higher average price levels. Higher average price levels in turn permit relatively inefficient firms to cover their fixed costs, and hence to remain in the market. Consequently, a positive effect of sunk costs on the productivity dispersion is predicted. The effect of fixed costs goes in the opposite direction. Higher fixed production costs lower the equilibrium productivity cutoff level and make it more difficult for inefficient producers to be profitable. Thus, all else equal, industries with high fixed costs shares are assumed to exhibit less dispersion and higher central tendency moments of the productivity distribution.

The current paper is similar in spirit to that of Syverson (2004b), which examines the effect of product diversification on productivity dispersion. In addition, we offer an empirical analysis that exploits the panel structure of our data. Further, industry-level product diversification is measured in a slightly different way. Syver-

[2] Only firms operating above this critical productivity cutoff level achieve nonnegative profits.

son's preferred proxy variable of aggregate product diversification (obtained for each four-digit SIC industry) is based on the production share of each product line (defined at a seven-digit SIC product classification system) within an industry. Using merely production shares of production lines has the disadvantage that it is impossible to disentangle whether an industry's output is divided among a large number of establishments or whether the total industry output is exclusively produced by one firm. Further, Syverson's approach neglects the fact that firms do not only pursue diversification strategies within the boundary of the industry they are assigned to according to the industry classification scheme, but also diversify into related or unrelated product markets. As a consequence, we follow Gollop and Monahan (1991) and derive an aggregate industry diversification index that will be based in the first step on the degree of diversification measured at the level of firms. Section 3 discusses the manner in which may be developed such a diversification index. But before this, it is necessary to refer to the motivation of firms to engage in product diversification. Further, we have to identify a link between the aggregate degree of diversification and within-industry productivity dispersion.

2.2 Diversification Motives and the Link to Productivity Dispersion

The motivation of firms to diversify has been studied extensively by both economists and business researchers. Though the literature offers a great variety of perspectives that synthesize a number of individual points, it seems to be reasonable to categorize three main ways of thinking. We distinguish between the resource-, the agency-, and the market power view.[3]

The resource view states that firms enter new markets in response to unused productive resources (Penrose, 1959; Teece, 1980). The existence of unused resources such as knowledge and technology is due to learning processes that occur in the course of operating a business. Resources, however, are deeply embedded in the routines of a firm (Nelson and Winter, 1982), and cannot be effectively sold in the market. Consequently, a firm has an incentive to expand to new markets since only this provides a reasonable way to absorb its underused resources and to generate economies of scope (Teece, 1982).

[3] See Montgomery (1994), Ramanujam and Varadarajan (1989), and Jovanovic and Gilbert (1993) for an overview of the various motives to diversification.

The market power view emphasizes possible anti-competitive strategies followed by diversified firms. The most prominent argument in this regard is the possibility for cross subsidization, in which a firm uses its profits from one market to support predatory power in another. The opportunity to engage in predatory pricing disciplines rivals planning to cut prices, and deters potential entrants by establishing market entry barriers.

The agency view stresses the fact that managers follow strategies that are not in line with the profit maximization interest of shareholders (Marris, 1964; Mueller, 1969). Besides the motivational commitment of empire-building it is argued that managers pursue diversification in order to reduce total firm risk, and thus their personal employment risk (Montgomery, 1994). As pointed out by Markham (1973), benefits from product diversification originate from combining businesses with earnings streams that are not highly correlated. Weston and Mansingka (1971) defined this kind of diversification as 'defensive diversification' which protects a firm's earning stream from adverse environmental changes taking place in its home market. Hence, product diversification can be regarded as a special form of a portfolio selection strategy that induces capital lenders to attach smaller risk premiums due to a reduced likelihood of bankruptcy (Markowitz, 1952).

We now come to the question why we expect a positive correlation between product diversification and productivity dispersion at the industry-level. In this respect, the agency- and the market power view play a vital role. One possible source for an interdependence is associated with the 'defense diversification' motive of firms. When a firm spreads its activities across different markets, it does not solely have to rely on profits generated by its main activity. This decreases the vulnerability to external shocks, and thus the danger of market exit. Consider for illustrative purposes the case of a firm that is not diversified at all, i.e., produces in just one industry. According to Syverson (2004b), this firm would be able to survive in the long-run if, and only if, its productivity level is well above the industry cutoff level. Now suppose an external shock triggered by an innovation occurs that shifts the industry productivity cutoff level beyond the firm's current productivity level. In this case, the undiversified firm becomes extremely vulnerable to market exit, since the coverage of fixed costs is no longer given. In contrast, a diversified firm exhibiting the same productivity level as the undiversified firm can still rely on positive profits generated in other business lines to cover fixed costs. This gives the diversified firm more time to adapt to the external shock, and does not immediately lead to a market exit. Hence, diversified firms are much more resistant towards selection forces than undiversified firms. Now suppose an industry is characterized by a large share of firms that carry out product diversification strategies causing a high average degree of diversification across industry establishments. If our conjecture holds, the selection process in this kind of industry is much weaker compared to industries featuring lower degrees of average product diversification. Since decreases in the toughness of competition due to diversification allow relatively inefficient producers to keep on operating, we expect a positive relationship between the average degree of product diversification and within-industry productivity dispersion.

Another potential source for an interdependence is associated with the market power-view, and can be found in the literature on interfirm competition. Most remarkable in this context is the formal analysis offered by Bernheim and Whinston (1990) that links patterns of interfirm rivalry to competitive conditions in the industry. The model by Bernheim and Whinston (1990) is based on what is known in the literature as 'mutual forbearance' (Edwards, 1995). Mutual forbearance means that firms frequently encounter each other in multiple product markets recognize their interdependence and compete less vigorously, because they weight the prospect of advantage in one market against the danger of retaliatory attacks in other markets. The outcome of multimarket interaction is therefore a reduction in competition (Baum and Korn, 1996). Since product diversification by its nature increases the probability of diversified companies to meet each other in multiple markets, we consider the aggregate degree of product diversification in an industry to be an indicator of the potential of mutual forbearance. As mutual forbearance implies an undermining of competition forces, inefficient producers are more likely to stay in the market. This tends to increase productivity disparity, and thus a positive relationship between aggregate product diversification and productivity dispersion at the industry-level is expected.

2.3 Different Patterns of Diversification across Industries

After a discussion of potential motives of firms to engage in diversification and a detection of a link between diversification and productivity dispersion, it is noteworthy to emphasize that a firm's decision to diversify heavily depends on the industry in which it is actually operating. Not all industries in the same manner offer the potential to diversify. Numerous empirical studies show remarkable inter-industry differences in the pattern of diversification (see Gollop and Monahan, 1991; Carleton et al., 1984; among others). The reasons for inter-industry differences are manifold, but technology-related explanations are mostly prevalent. We have already pointed out that resources have long been recognized to be among the key factors in explaining product diversification. If a firm possess excess resources being flexible enough to be applied outside the firm's primary activity, it has an incentive to expand. However, as Gorecki (1975) emphasizes, before a specific resource can be transferred outside the core market, it has to be modified or adapted. This process involves costs which heavily impinge on a firm's decision to diversify. Chatterjee and Wernerfelt (1991) point out that those transfer costs are smaller the more homogeneous industries are with respect to their technological nature. In this view, it is not surprising that Lemelin (1982) and Carleton et al. (1984) find that firms tend to diversify into industries which use resources similar to their own. More recently, Breschi et al. (2003) tested the extent to which firms diversify their innovative activities across related technological fields. Their results show that firms follow a coherent pattern of technological diversification. In fact, firms diversify into technological fields and industries that share a common or complementary knowledge base, rely upon common scientific principles or have similar heuristics of search. However, there are remarkable differences across industries with respect to the potential to transfer knowledge and production technologies into related fields. Consider, for instance, the textile industry. The textile industry provides the opportunity for broad product diversification strategies because of the large spectrum of sub-segments that all require similar technological competences. Moreover, parts of the technology used to produce textiles can also be applied in related sectors such as footwear production. Petroleum processing can be regarded as another extreme case. Here, firms are much more restricted by the range of possible applications of their technology. The few number of sub-segments makes it hard for firms to accomplish related diversification strategies. Further, since the production technology used is highly specialized, also an unrelated diversification is virtually impossible.

3 Data and Methodology

Our analysis is based on micro data from the German Cost Structure Census of Manufacturing,[4] the Monthly Report of Local Units in Manufacturing,[5] and the Production Census of Manufacturing[6] over the time period 2003 to 2006. The Cost Structure Census of the German Federal Statistical Office is an annually conducted representative random sample survey of around 18,000 companies in the manufacturing sector with at least 20 employees. It is a full census of all firms with over 499 employees.[7] For all other reporting units, it consists of a representative rotating sample with panel properties. The random sample quota for firms with 20 to 249 employees is 38 percent, and 73 percent for firms with 250 to 499 employees. The cost structure survey offers various information including industry affiliation, type of business, final output, number of employees, number and amount of R&D expenditure as well as the number of R&D employees payroll, received subsidies, employer contributions to the social security system, fringe benefits, expenditures for material inputs, energy expenditures and taxes. The Monthly Report of Establishments in Manufacturing is a questionnaire that is used to derive data about domestic and non-domestic turnover as well the number of hours worked. Since the monthly report is conducted at the establishment level, we aggregate the information over all months, and all establishments belonging to the same firm. The Production Census of Manufacturing is a monthly/quarterly[8] report of manufacturing establishments on the type, amount, and value of products produced. The respective product data is collected at a four-digit product classification level. For the purpose of this paper, we assign the establishment-level data to the relevant firms and aggregate to annual figures. We then proceed by building a producer-product-panel that merges the information from the Cost Structure Survey, the Monthly Report of Establishments in Manufacturing, and the Production Census of Manufacturing. The resulting unbalanced panel contains relevant information of 16.442 firms in 189 four-digit manufacturing industries.[9] Since the aim of the paper is to investigate the relationship between product diversification and productivity dispersion, we use the data from

[4] Kostenstrukturerhebung im Verarbeitenden Gewerbe sowie des Bergbaus und der Gewinnung von Steinen und Erden.

[5] Monatsbericht für Betriebe des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden.

[6] Produktionserhebung im Verarbeitenden Gewerbe sowie des Bergbaus und der Gewinnung von Steinen und Erden.

[7] See Fritsch et al. (2004) for further details.

[8] Firms or establishments with fewer than 20 employees are required to report quarterly.

[9] All firm belonging to the sub-sectors mining and quarrying are excluded.

the producer-product-panel to construct aggregate measures of diversification and a number of control variables at a four-digit industry level.

In our econometric analysis, we are interested in a relationship between product diversification and intra-industry productivity heterogeneity. If our conjecture holds, higher amounts of aggregate product diversification should be associated with higher levels of productivity dispersion. The presumed link is due to the fact that diversification strategies allow relatively unproductive firms to escape intense competition forces and to survive in the longer run. This in turn causes persistent productivity differentials and lower central tendency moments in the productivity distribution for industries with high degrees of aggregate product diversification. In order to test our hypothesis empirically, we use the following econometric specification:

$$y_{it} = \alpha + \beta div_{it} + \gamma^{'} X_{it} + \mu_i + \lambda_t + e_{it} \qquad i = 1, ..., n \qquad t = 1, ..., T \qquad (1)$$

where y_{it} is a measure of the productivity dispersion in industry i at point in time t, μ_i is a industry fixed effect, λ_t a time fixed effect, and ε_{it} is the error term. The aggregate degree of product diversification of industry i at time t is denoted by div_{it}. X_{it} are other exogenous control variables. Using the data from our producer-product-panel, we compute labor productivity distribution moments for each four-digit manufacturing industry. Labor productivity at the firm-level is measured as the logarithm of value added per employee-hour. Value added is calculated as the difference between gross value added and all intermediate inputs.[10] We follow Syverson (2004b) and employ two different measures in order to quantify intra-industry productivity differences. We measure industry productivity dispersion as the interdecile productivity range (IDR), which is the distance between the 90^{th} percentile and the 10^{th} percentile of the within-industry productivity distribution. Alternatively, we use the interquartile range (IQR) of the productivity distribution to test the robustness of our results with respect to a modified productivity dispersion measure. Further, since aggregate product diversification might not only affect the lower and the upper ends of the productivity distribution, we also incorporate a central tendency moment

[10] We could not compute total factor productivity (TFP) as an alternative productivity measure since TFP estimation requires information on investments or a firm's capital stock. Unfortunately, these data are not available in German Cost Structure Survey of Manufacturing.

in our analysis. In fact, we calculate the mean labor productivity for each industry (MP) and regress it on measures of aggregate industry product diversification.

Aggregate product diversification, div_{it}, our variable of primary interest, is calculated as follows. First, we measure the degree of product diversification for each firm. Then we derive an aggregate industry diversification index by taking the average across all four-digit industry establishments. Product diversification at the firm-level is measured in two ways. First, by the primary product specialization index (PPS), which is based on the share of sales of the most important product in total sales.[11] The primary product specialization index for firm k is given by

$$PPS_k = 1 - s_{max,k} \tag{2}$$

where $s_{max,k}$ denotes the fraction of sales accounted for by products within the industry's primary product class (as assigned by the four-digit product-level taxonomy). By definition, for a single-product firm, the share of sales of the most import product in total sales is equal to one. Thus, the primary product specialization index is zero which indicates that a firm is not diversified at all. Second, we employ a Shannon (1948) entropy index (*entropy*) which is defined as

$$entropy_k = \sum_l s_{kl} \cdot \ln\left(1/s_{kl}\right) \tag{3}$$

where s_{kl} indexes the share of product l in total sales of firm k.

We must point out that the productivity distribution of an industry might also be affected by other influences. These additional factors are summarized in the vector of control variables X_{it}. As described, both sunk entry costs and fixed operating costs are likely to impinge on the moments of the distribution. In the empirical analysis, the average capital intensity (*capital intensity*) across industry establishments is used as a proxy for sunk costs of entry. Capital intensity is defined as the user cost of capital (depreciation plus rents and leases) per employee. Although user cost of capital will not be a perfect measure of tangible capital requirements to start production, it is plausible to assume that they are highly correlated with a firm's

[11] For an overview about various diversification measures, see Gollop and Monahan (1991).

capital stock (Hölzl, 2003). Hence, our capital intensity measure will adequately account for mobility barriers negatively influencing entry and exit, and therefore the moments of the labor productivity distribution. Fixed operating costs (*fixed costs*) are obtained by the ratio of labor costs (wages and salaries plus social insurance) to total costs, averaged across all industry establishments. Because of the prevailing labor market rigidities in Germany preventing employer from rapidly changing wages, salaries and the number of employees, the ratio should effectively capture fixed costs of production. In order to control for technology and innovation related factors that shape the within-industry productivity distribution, we incorporate the average R&D intensity (*R&D intensity*) of a sector in our econometric model. R&D intensity at the firm-level is defined as the share of R&D workers in the total workforce. Another possible explanation of persistent productivity dispersion is the openness to trade. We use the export intensity (*export intensity*) as a proxy for international trade exposure. Export intensity is calculated as the share of exports in total industry output. As a proxy for output market competition and market imperfections, we introduce a Hirschman-Herfindahl index (*concentration*). The index is measured as the sum of square of each firm's sales share in the respective four-digit industry. Further, we control for market size effects by including total industry sales (*market size*) in the analysis. It was pointed out above that market intervention policies might also impinge on the moments of the productivity distribution. We try to account for that by computing an industry's subsidy intensity (*subsidy intensity*), which is defined as the amount of total subsidies granted divided by total industry output. A summary of variable definitions is reported in Table 1.

Table 1: Definition of variables

Name	**Definition**
Interdecile Range (IDR)	Distance between the 90^{th} percentile and the 10^{th} percentile of the within-industry productivity distribution.
Interquartile Range (IQR)	Distance between the 75^{th} percentile and the 25^{th} percentile of the within-industry productivity distribution.
Mean Labor Productivity (MP)	Mean industry labor productivity level.
PPS	One minus the share of sales accounted for by the primary product averaged across industry establishments.
Entropy	Entropy measure of diversification averaged across industry establishments.
Capital Intensity	User cost of capital (depreciation plus rents and leases) per employee averaged across industry establishments.
Fixed Costs	Ratio of labor costs (wages and salaries plus social insurance) to total costs averaged across industry establishments.
Subsidy Intensity	Total amount of granted subsidies divided by total industry output.
Export Intensity	Share of exports in total industry output.
Concentration	Hirschman-Herfindahl index of concentration.
R&D Intensity	Share of R&D workers in the total workforce averaged across industry establishments.
Market Size	Total industry sales.

4 Empirical Results

Summary statistics are presented in Table 2. As can be seen, the average within-industry interquartile range of logged labor productivity values is roughly 0.85. This indicates large intra-industry differences in productivity. Including more of the tails of the productivity distribution amplifies intra-industry heterogeneity. The average interdecentile productivity range is 1.68. Table 3 displays pairwise correlation coefficients. In general, the correlations among the independent variables show that we should not expect problems arising from multicollinearity. Further, a coefficient of 0.86 between *PPS* and *entropy* reveals that both measures of aggregate product diversification are highly correlated.

Table 2: Summary statistics of employed variables

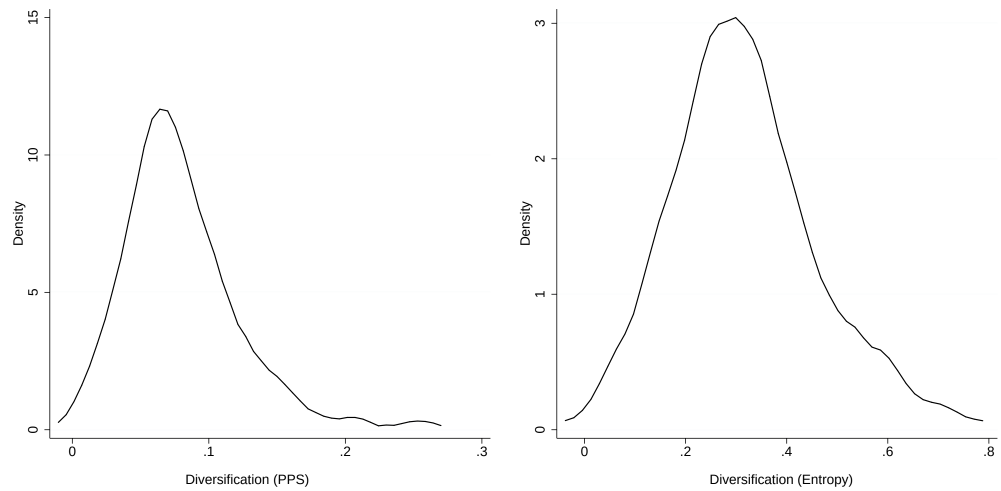
	Obs.	**Mean**	**Std. Dev.**	**Min**	**Max**
Interdecentile Range (IDR)	752	1.678	0.458	0.785	4.243
Interquartile Range (IQR)	752	0.854	0.258	0.382	2.951
Mean Productivity (MP)	752	3.224	0.273	2.581	4.796
Diversification (PPS)	752	0.079	0.042	0	0.268
Diversification (Entropy)	752	0.311	0.139	0	0.807
Capital Intensity	752	9094	4559	2933	39099
Fixed Costs	752	0.543	0.077	0.235	0.699
Subsidy Intensity	752	0.000	0.002	0	0.034
Export Intensity	752	0.334	0.186	0.002	0.799
Concentration	752	0.106	0.088	0.014	0.562
R&D Intensity	752	0.020	0.023	0	0.114
Market Size	752	5.82E+09	1.50E+10	1.33E+08	1.74E+11

In section 2 of this paper, it is suggested that not all industries in the same manner offer the opportunity for firms to diversify. We expect remarkable inter-industry differences in the pattern of diversification. In order to illustrate inter-industry differences, we plot Kernel density estimates of the aggregate primary product specialization index (*PPS*) and of the aggregate entropy index across all 189 four-digit industries in Figure 1. Indeed, the graphs show that there are significant differences across industries with respect to the average degree of diversification.

Table 3: Pairwise correlation coefficients

	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	11)	12)
1) IDR	1											
2) IQR	0.750	1										
3) MP	0.369	0.243	1									
4) PPS	0.236	0.251	-0.259	1								
5) Entropy	0.280	0.296	-0.219	0.856	1							
6) Capital Intensity	0.325	0.133	0.421	0.266	0.143	1						
7) Fixed Costs	-0.471	-0.368	-0.417	-0.093	-0.060	-0.660	1					
8) Subsidy Intensity	-0.024	-0.017	-0.022	-0.047	-0.038	-0.023	0.000	1				
9) Export Intensity	-0.052	0.018	0.077	0.093	0.140	-0.143	0.336	0.031	1			
10) Concentration	0.244	0.213	0.082	0.183	0.188	0.163	-0.164	-0.027	0.177	1		
11) R&D Intensity	0.180	0.156	0.151	0.146	0.229	0.070	0.175	0.000	0.475	0.258	1	
12) Market Size	0.317	0.173	0.266	0.095	0.051	0.474	-0.122	-0.018	0.075	0.133	0.269	1

Figure 1: Inter-industry differences in the pattern of diversification



In order to estimate the parameter of regression equation (1), we use a fixed effects model. Employing a fixed effects model specification allows us to control for other unobserved time-invariant influences. We believe this is a notable advantage over related studies that merely rely on cross-sectional analysis (see Syverson, 2004b; Balasubramanian and Sivadasan, 2009). The estimation results are summarized in Table 4.

In Table 4, we show the results of regressing the interdecile productivity range (i.e., the distance between the 90^{th} percentile and the 10^{th} percentile of the within-industry productivity distribution) on the industry product diversification measures and the control variables. In column 1 to column 3, we show the results of using the primary product specialization index (PPS) to capture the degree of product diversification of an industry. The conclusion is that aggregate product diversification of an industry is positively and significantly related to an industry's labor productivity dispersion. In column 1, we find estimates from a benchmark fixed effects model with year fixed effects. We see that the inclusion of addition controls (Model 2 and Model 3) does not affect the basic result. The coefficient for product diversification remains positive and significant. Further, we see that the incorporation of additional covariates does not substantially increase the fit of model. The within R-squared increases only slightly from 0.045 (Model 1) to 0.062 (Model 3). This suggests that aggregate product

Table 4: Product diversification and interdecile productivity range

Dep. Variable: IDR	(1)	(2)	(3)	(4)	(5)	(6)
PPS	3.946***	3.917***	3.937***			
	(1.160)	(1.159)	(1.118)			
Entropy				1.072***	1.079***	1.108***
				(0.283)	(0.276)	(0.268)
Capital Intensity		0.000	0.000		7.89e-06	9.66e-06
		(0.000)	(0.000)		(0.000)	(0.000)
Fixed Costs		-0.807	-0.085		-1.041	-1.099
		(1.430)	(1.145)		(1.429)	(1.446)
Subsidy Intensity			7.565**			7.780**
			(3.133)			(3.135)
Export Intensity			-0.294			-0.325
			(0.366)			(0.373)
Concentration			0.754			0.824
			(0.570)			(0.531)
R&D Intensity			-1.015			-1.050
			(2.863)			(2.771)
Market Size			1.66e-12			7.52e-13
			(0.000)			(0.000)
Constant	1.382***	1.7135*	1.744*	1.359***	1.861**	1.901
	(0.092)	(0.891)	(0.928)	(0.090)	(0.891)	(0.921)
Time Dummies	yes	yes	yes	yes	yes	yes
Observations	752	752	752	752	752	752
R^2- within	0.045	0.049	0.062	0.049	0.053	0.068
R^2- between	0.058	0.181	0.210	0.083	0.250	0.258
R^2- overall	0.056	0.166	0.193	0.079	0.228	0.236
Prob > F	0.008	0.026	0.021	0.000	0.000	0.000

*Notes: The estimation method is fixed effects. Robust standard errors are reported in parentheses. *** 1% level of significance, ** 5% level of significance, * 10% level of significance.*

diversification is one of the crucial factors in explaining productivity heterogeneity. In columns 4 to 6, we show estimates from the model using the entropy index (*entropy*) of diversification as a covariate. The coefficients of diversification keep their signs and significance. The findings obtained are in line with our expectation. We argue that a high degree of aggregate product diversification indicates that industry firms spread their business activities across different markets. This makes firms less vulnerable to external shocks and competition-driven selection forces, and thus decreases the likelihood of market exit. We also point out that product diversification increases the likelihood of collusive behavior. Less intense competition due to collusive behavior leads to a decline of the industry productivity cutoff level, and consequently to an increase of productivity disparity.[12]

The estimation results of Table 4 reveal that also *subsidy intensity* influences the productivity dispersion of industries. A positive and significant coefficient for subsidy intensity (Model 3 and Model 6) could indicate that competition forces are weaker in sectors where inefficient producer receive public funds. As a result, low performers might be tempted to remain in the market. This shapes the left tail of the productivity distribution and increases the productivity dispersion. Although having in principle the expected signs, the estimated coefficients for sunk costs (*capital intensity*), *fixed costs*, *R&D intensity*, *market size* and market concentration (*concentration*) are all insignificant. A possible explanation for the statistical insignificance could be the short time span (2003-2006) of our analysis. An assessment of the respective variables shows that they do not change much over time. The low within-variation is certainly a driving force behind the observed insignificance.[13] In future research, it is intended to expand the dataset to longer time periods. This will definitely help us to explore the impact of these variables on the productivity dispersion more effectively.

In order to ensure that our previous findings do not depend on the measurement of productivity dispersion, Table A.1 in the Appendix reports the estimation results employing the interquartile range (i.e., the distance between the 75^{th} percentile and the 25^{th} percentile of the within-industry productivity distribution) of the intra-industry productivity distribution as the dependent variable. The estimation outcomes show a strong positive correlation between aggregate product diversification and productivity dispersion, irrespective of the measurement of product diversification. Also the coefficients for *subsidy intensity* are positive and significant. Contrary to our previous results, we obtain positive and significant estimates for *market size*. This finding

[12] We control for a non-linear relationship between aggregate product diversification and productivity dispersion by including squared terms of the respective measures in the econometric model. The insignificance of the coefficients that we obtain does not suggest the existence of a non-linear relationship.

[13] The ability of controlling for the potentially large number of unmeasured explanatory variables by estimating a fixed-effects model comes at a certain price. The problem of estimating time-invariant variables in panel data analyses with unit effects has been widely recognized: since the fixed-effects model uses only the within-variance for the estimation and disregards the between-variance, it does not allow the estimation of (almost) time-invariant variables (Wooldridge, 2002). However, since we are solely interested in the coefficients of the time-variant variables, namely our aggregate product diversification measures *PPS* and *entropy*, the application of a fixed-effects model specification is justified. Note that fitting a random-effects model by using the between regression estimator yield no qualitative changes for the parameter estimates of the variables of interest.

is not in line with economic theory suggesting that market size negatively affects productivity dispersion (see Melitz and Ottaviano, 2008). A potential explanation could be that increases in market size may attract potential entrants causing higher variation of intra-industry productivity.

So far we have focused on the impact of product diversification on the dispersion moments of the productivity distribution. In the following, we also want to assess the influence of aggregate diversification on another moment of the distribution, namely the mean industry productivity level (MP). In order to do so, we regress the mean industry productivity on aggregate product diversification. The results are shown in Table 5.

Table 5: Product diversification and mean industry productivity

Dep. Variable: MP	(13)	(14)	(15)	(16)	(17)	(18)
PPS	-2.253*** (0.419)	-2.204*** (0.404)	-2.183*** (0.379)			
Entropy				-0.430*** (0.116)	-0.403*** (0.112)	-0.416*** (0.096)
Capital Intensity		-9.50e-06 (0.000)	-0.000 (0.000)		-8.64e-06 (0.000)	-0.000 (0.000)
Fixed Costs		-0.908** (0.432)	-0.892** (0.429)		-0.845* (0.447)	-0.824** (0.441)
Subsidy Intensity			-1.294 (1.892)			-1.161 (1.710)
Export Intensity			-0.072 (0.112)			-0.068 (0.119
Concentration			-0.285 (0.189)			-0.325 (0.215)
R&D Intensity			0.167 (0.908)			0.106 (0.945)
Market Size			8.14e-12** (0.000)			8.47e-12** (0.000)
Constant	3.353*** (0.033)	3.934*** (0.281)	3.953*** (0.302)	3.301 (0.037)	3.842*** (0.290)	3.867*** (0.308)
Time Dummies	yes	yes	yes	yes	yes	yes
Observations	752	752	752	752	752	752
R^2- within	0.357	0.370	0.399	0.328	0.339	0.371
R^2- between	0.066	0.100	0.153	0.049	0.088	0.125
R^2- overall	0.084	0.113	0.167	0.067	0.105	0.140
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000

*Note: The estimation method is fixed effects. Robust standard errors are reported in parentheses. *** 1% level of significance, ** 5% level of significance, * 10% level of significance.*

Table 5 reveals negative and significant coefficients for aggregate product diversification (*PPS* and *entropy*). This implies that higher amounts of aggregate product diversification tend to lower mean productivity levels. This result is consistent with findings of related empirical studies (e.g., Syverson, 2004b; Balasubramanian and Sivadasan, 2009). The estimated coefficients for *fixed costs* are negative and significant which is not fully in line with our expectation. According to theory, higher fixed costs should make it more difficult for inefficient producers to be profitable triggering their market exit. As a result, increases of fixed costs are expected to lead to higher mean productivity levels. For the *subsidy intensity,* we obtain negative coefficients supporting our conjecture that subsidies predominantly benefit producers from the lower tail of the productivity distribution. However, the estimated coefficients are insignificant. The coefficients for *market size* are positive and significant. A possible explanation for a positive impact of *market size* on mean productivity could be the existence of economies of scale. In larger industries, it is more likely that companies achieve efficiency gains through economies of scale which results in higher mean productivity levels. Similar to our previous findings, the parameter estimates of all other control variables turn out to be insignificant.

5 Conclusions

The aim of this paper was to explore a systematic relationship between the degree of product diversification and productivity dispersion at an industry-level. Using a panel dataset for German manufacturing industries over the period 2003-2006, we find that the aggregate degree of product diversification of an industry is positively related to intra-industry labor productivity disparity. As discussed in the course of this study, high levels of aggregate product diversification indicate that industry firms spread their business activities across different product markets. This kind of portfolio strategy makes firms less vulnerable to external shocks and increases the likelihood of collusive behavior. As a consequence, the competition-driven selection process within an industry is weakened, causing persistent productivity differentials across firms, even within narrowly defined industries. We attempt to control for a number of other influences identified in the theoretical and empirical literature. Although some of the controls may be imperfect, the robustness of our findings implies that they do not severely affect our general result. In this respect, our study makes an important contribution to the existing literature, since the role played by aggregate product diversification in explaining performance heterogeneity has been neglected by empirical research so far. Finally, though the focus was on the impact of product diversification, our empirical analysis has shown further interesting regularities in the relationship between some of the control variables and the dependent variable. Especially, the role played by public subsidies definitely deserves more attention in future research.

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A Appendix

A.1 Product diversification and interquartile productivity range

Dep. Variable: IQR	(7)	(8)	(9)	(10)	(11)	(12)
PPS	2.180***	2.160***	2.142***			
	(0.628)	(0.620)	(0.624)			
Entropy				0.543***	0.541***	0.538***
				(0.164)	(0.164)	(0.168)
Capital Intensity		6.49e-06	4.88e-06		4.17e-06	2.66e-06
		(0.000)	(0.000)		(0.000)	(0.000)
Fixed Costs		-0.090	0.098		-0.201	-0.211
		(0.567)	(0.556)		(0.578)	(0.566)
Subsidy Intensity			4.412**			4.447**
			(2.104)			(2.060)
Export Intensity			-0.124			0.167
			(0.141)			(0.146)
Concentration			0.242			0.280
			(0.292)			(0.259)
R&D Intensity			1.886			1.893
			(1.449)			(1.538)
Market Size			4.82e-12***			4.38e-12**
			(0.000)			(0.000)
Constant	0.686***	0.680*	0.649	0.689***	0.763**	0.734*
	(0.049)	(0.369)	(0.372	(0.052)	(0.370)	(0.372)
Time Dummies	yes	yes	yes	yes	yes	yes
Observations	752	752	752	752	752	752
R^2- within	0.039	0.040	0.055	0.037	0.038	0.052
R^2- between	0.070	0.087	0.122	0.098	0.146	0.163
R^2- overall	0.064	0.079	0.111	0.088	0.130	0.148
Prob > F	0.007	0.023	0.008	0.010	0.039	0.008

*Notes: The estimation method is fixed effects. Robust standard errors are reported in parentheses. *** 1% level of significance, ** 5% level of significance, * 10% level of significance.*