

**Report to the
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Directorate General for Research and Innovation
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**Recent Trends in Manufacturing Globalization and Their Effects on the
Distribution of R&D, Design, and Production within US, German and Japanese
Automobile, Electro-Mechanical, Machinery and related Component MNCs**

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The relative shift of world manufacturing demand toward China, other Brics and emerging markets (especially in eastern Europe and Asia) has generated a significant change in the character of European, US and Japanese manufacturing MNC global strategies. These developments have implications for upgrading in emerging markets, and are recasting home country labor market, production and R&D strategies. Global manufacturing competence allocation is being recomposed in an historically distinctive way.

Previously, global manufacturers serviced demand in emerging economies primarily through exports or through low technology, production-only FDI projects. Sophisticated FDI involving state of the art manufacturing, elaborate local supply chains and application intensive R&D was confined to operations in the advanced political economies. This pattern is changing as current emerging economy demand growth levels overwhelm the relatively flat rates of manufacturing demand growth in developed markets. Looking for growth, developed country manufacturing MNCs are naturally turning to these emerging markets. Moreover, in order to be competitive there, those MNCs need to produce locally and accommodate their products to host country standards, regulations and growing indigenous customer sophistication. This “produce where you sell” strategy involves considerable upgrading for MNC operations in markets such as China: Production facilities need to be made more sophisticated, supply chains must be improved, and local R&D, design and engineering competence must be expanded.

These developments abroad have significantly affected developed country MNC internal governance processes and home country operations. From a governance perspective, MNCs are developing global monitoring and exchange systems that both support disparate local technical and organizational experimentation processes and capture and distribute promising developments from those locations to other MNC operations that

could profit from them. Corporate production systems and the cultivation of a globally circulating engineer and technician cohort facilitate these learning and innovation oriented governance practices.¹

These developments are recomposing MNC home locations in three significant ways. First, home location centrality for future oriented R&D is both solidifying and expanding in scope. Central R&D participates at various levels in global product development teams, and collaborates with engineering and manufacturing counterparts in all global locations. The qualitative and quantitative demands on central competence are, as a result, increasing enormously. Firms need to expand their home location engineering workforce to accommodate this. Second, driven by the new internal governance practices noted above, home country R&D competence is drawn into a support role for far flung MNC technical experimentation processes. Such activities are growing *along with* the expansion of competence and production sophistication abroad, thus increasing home country demand for production engineers and technicians. Third, home market production operations are also changing significantly as a result of offshore upgrading. The same “produce where you sell” logic that leads firms to expand their production and development operations abroad leads them to *retain production and development competences at home*. Unlike the engineering part of the workforce, however, these developments are unlikely to lead to higher levels of skilled worker employment, although demand for highly skilled production workers is likely to become more uniform. In particular, because home country R&D operations have expanded, the need for home location prototyping, small batch and quick turnaround manufacturing capacity has expanded accordingly. These practices rely heavily on skilled production labor.

This report will briefly sketch these changes in three sections, drawing on comparative evidence from shifting global strategies in the automobile, component, machinery and electrical mechanical industries, primarily in Germany and the US. Additional comparative data from other sectors and from Japan will be introduced where possible. Emphasis will be less on the processes of upgrading in China and elsewhere and more on the recursive consequences of this upgrading on MNC home country operations and policies. Particular attention will be placed on the effect that these dynamics have on global MNC R&D and engineering competence allocation.

The first section outlines the global transformation of manufacturing demand and production location driving the shift toward “produce where you sell”. The second section discusses the consequences of those shifts for home country operations, in particular with respect to home country research and innovation activities. The third section then examines the implications that these shifts have for industrial, labor market, education and R&D policies.

A) Global industrial demand and production: The rise of emerging economies and the shift to “produce where you sell”

¹ This is the focus of Herrigel et Al 2013

From a developed country manufacturing MNC point view, global opportunities for growth and expansion have shifted notably in the new century. For most of the twentieth century, the largest markets for manufactured goods were also the fastest growing ones. For US, German and Japanese manufacturers, this meant that the bulk of their exports and FDI efforts targeted the developed (western) European, North American and North Asian economies. This situation began to change in the last decade, however, and most forecasting agencies suggest that the new trends are likely to accelerate in the next several decades². For example, the Economist Intelligence Unit (2011) expects world real GDP growth to increase approximately 4% yearly between 2010 and 2015, but OECD country growth rates are expected to be only roughly 2% yearly, while non-OECD annual growth is expected to exceed 7% for the same time period. A different measure by the same institution shows that Asia (including Japan) is expected to grow twice as fast as the rest of the world over the same time period (Table 1). In the same vein, the German Chamber of Commerce estimates that China will go from having a third the number of potential middle class consumers as the United States (70 million to 236 million) in 2001 to having well over twice as many of those potential consumers in 2015 (700 million to 284 million).³ The later number shows that while current trends represent a relative shift in the expansion of demand, rather than an absolute shift in its location, the quantitative levels separating the two markets are narrowing rapidly as well.

In many specific industrial product areas, from consumer electronics items and automobiles to hydro-electric turbines, the contrasting demand situations are quite dramatic. Developed markets have reached points of saturation where demand is primarily driven by replacement of existing product (when demand expands at all it is doing so in the low single digits), while demand for the same products in developing Asia or other Brics is growing in double digits. In the global electronic and electromechanical products, for example, Deutsche Bank Research shows that between 1998 and 2007 demand grew at a less than 2% rate in the US and Germany, while demand for the same products in China, Russia, Indonesia and Malaysia exceeded 10% (Table 2). Similar imbalances can be observed in global machinery and automobile markets. In 2000, for example, the German Automobile Association (VDA) notes that developing countries accounted for just 22.3% of global automobile demand, but this percentage is expected to increase to 48% by 2020 (table 3). The picture is very similar in the machinery industry. The German Machinery Association (VDMA) shows that by 2011 China had emerged as the world's single largest machinery producing country, selling nearly twice as many machines (of all types)—230 billion Euros to 563 billion Euros—as Germany (Table 4). Our interviews with a German manufacturer of hydro-electric turbines revealed that the company currently only sells replacement parts and components in Europe and North America. All of new global demand for turn-key hydro-electric generating complexes comes from Latin America, Asia and Africa.

These very significant relative shifts in manufacturing demand growth have resulted in a massive strategic shift in the relative weight of export vs FDI and in MNC strategies in

² For example, see Bergheim 2005, Trinh 2004, 2006, Dyck et Al 2009, Walter 2007

³ Reinhardt 2009

developing economies. In short, emerging market demand growth has been so rapid, technologically challenging and quantitatively massive that it cannot be serviced through exports alone. Instead, firms have been forced to expand FDI and service demand in those emerging markets by “producing where they sell”. The shift has been very rapid: US non-financial FDI in China, for example, grew by more than 40% between 1984-2004, but off a very small base.⁴ Given the growth of income and internal demand in China, however, NBER analysts estimate that levels of US non-financial FDI affiliate sales in China is likely to triple in the next decade.⁵ Japanese, German, South Korean and Taiwanese non-financial FDI has followed a similar pattern (Japanese levels of China investment are slightly higher than those in the US; German, Taiwanese and S. Korean slightly less). Manufacturing has been the dominant form of FDI into China, and though rising Chinese wage costs have tempered FDI, the most believe that China will remain a strong destination for manufacturing FDI for quite a long time.

Viewed by sector, the shift between export and FDI is very clear. German automobile producers, for example, currently manufacture more vehicles outside of Germany than they produce inside of Germany (Table 5). By far, the largest off shore production location for German car makers is China, followed by Spain, Brazil, the Czech Republic and Mexico (Table 6). The trend has been similar for Japanese automobile producers. An OECD study shows that in 2000 Japanese producers made only 7.3% of their total output in Asia. By 2009, that figure had increased to 29.2%. Like their German counterparts, Japanese auto producers also manufacture more vehicles offshore than they do in Japan (58.4-42.6% in 2009) (Table 7). Similar trends are evident among US automobile producers. By 2006, both General Motors and Ford made more than half (for GM more than 60%) of their total production volume outside the US.⁶

Trends in Machinery production are less pronounced; exports still overwhelm off shore production in most machinery branches in the US, Germany and Japan. In part, this can be attributed to the small batch and customization orientation of many producers and the resulting ability of home facility capacity to accommodate the quantity and variety of world demand.⁷ But the orientation of exports and the trend in FDI in the sector follows the same general pattern being described here. Emerging markets, especially China, have garnered enormous amounts of output and FDI in the last ten years. Take, by way of illustration, the direction of German machine tool exports. In 1984, China accounted for only 1.2% of total exports, while the US was the largest single country buyer of (west) German exports, at 11.3%. By 2011, however, China had become Germany’s single largest export market, taking a full 29% of all machine tool exports. The US was the second largest buyer with a comparatively modest 9.1% share (Table 8). FDI trends follow this shift in exports. In the German case, while the US still remains the number one location for FDI (accounting for 15.7% of total German machinery FDI in 2006), China’s share was growing significantly. As late as 2001, China received only 2.1% of

⁴ Branstetter – Foley 2007 p3

⁵ Branstetter – Foley 2007 p 9

⁶ Moavenzadeh 2006

⁷ Fuchs & Kirchain 2010

total German machinery FDI. In 2006, China's share had grown to 5.2%.⁸

“Produce Where You Sell”

All of the above data indicates that there has been a clear shift to “producing where you sell” among developed economy manufacturing MNCs, and that important beneficiaries of this shift (though not the exclusive beneficiaries) have been emerging markets, such as, in particular, China and other economies in Asia. Crucially, this orientation shift involves significant offshore production operation upgrading. Competition for market share in growing markets such as China is intense and the sophistication of customers is developing rapidly. In order to be competitive, FDI manufacturers must pay attention to manufacturing economies and product quality. Moreover, the MNC affiliates must be able to offer products that appeal specifically to the needs and preferences of local customers and that are designed according to host country regulatory norms and standards. This presses manufacturers to upgrade local operations in three areas: production worker skill levels, supply base sophistication, and local R&D, design and engineering capability.

Work by Herrigel, Wittke and Voskamp⁹ has extensively outlined how skill levels, production organization and suppliers have been improving in China in the automobile and machinery industry and their supply chains. We will, as a result, only briefly sketch these developments here in order to be able to pay more attention to developments in R&D. Suffice it to say that foreign manufacturing MNCs have invested significant resources and have received remarkable support from, in particular, Chinese regional governments for vocational training. Initially, low wages made it possible for MNCs to deploy less automation in their production and assembly processes, but as skilled wages increase, so are levels of capital intensity and technical sophistication in production equipment. Local facilities have significant discretion regarding how labor and production is organized (and there are often significant differences between products made in home countries and those made in offshore locations) but American, German and Japanese producers all place great emphasis on the deployment of corporate production systems throughout their global operations.¹⁰

These formal systems, especially in their US and German incarnations, induce collective self monitoring in ways that join local discretion with centralized support and intervention. Local managers and teams can adapt to immediate host country challenges, but all changes from company global organizational or product standards must be justified to central teams. In this way, the center is in a position to lend local players support in their adaptation efforts, while at the same time being able to take successful subsidiary innovations and diffuse them to other locations within the global firm. At the level of production organization, then, manufacturing FDI increasingly becomes a

⁸ Herrigel 2013

⁹ Herrigel et Al 2013

¹⁰ for general discussion of the logic of corporate production systems, in addition to Herrigel et Al 2013, see Sabel 2005 and Spear 2009

peculiar mixture of local discretion, hybridization and global standardization. Our own research in the machinery and automobile industries, as well as parallel efforts in the literature, suggest that German and American firms are more tolerant of local discretion and hybridization than are their Japanese counterparts, although all deploy rigorous corporate production system techniques (in particular, company specific adaptations of lean production and six sigma practices).¹¹

Analogous processes of upgrading are occurring in emerging market supply chains. The key change here is that both MNC supplier firms, as well as indigenous emerging market suppliers active in transnational supply chains, are shifting their attention away from transnational activity and seeking, instead, to embed themselves in emerging market production networks oriented toward domestic rather than foreign markets.¹² MNC supplier firms, such as Robert Bosch or Magna, follow their customer's FDI activities to exploit their familiarity with the customer's production systems and benefit from new business in emerging markets. At the same time, such firms assume a teaching role for their customer's by developing the capabilities of indigenous suppliers. In China (or in Central Europe), there are many quite capable indigenous suppliers, with considerable experience in continuous improvement, lean practices, and collaboration with customers from many years of participation in transnational supply chains. These indigenous customers are normally process specialists without the ability to deliver a proprietary component of their own (I.e., second tier or below in the supply chain), so they must only be socialized in the particular practices of customer corporate production systems. It is a matter of learning the language and practices of customer interface.

First tier MNC suppliers specialize in this kind of socialization. At the same time that they attempt to develop the indigenous supply networks for their MNC customer subsidiaries, they also seek to insert themselves into the supply networks of their customers competitors—eg, Magna tries to get business in China with Geely or Hyundai and in that way provide diverse (less dependent) business for its China operations. Like their global customers, these global suppliers have their own corporate production systems and generate the same kinds of dynamics of local discretion, hybridity and global standards that characterize their customers practices. Indigenous Chinese, Polish, Brazilian and Indian suppliers embrace the same kinds of practices to the degree to which they are engaged with foreign MNCs.¹³ These kinds of dynamics are most strongly characteristic of the automobile industry and the larger production series oriented branches of machinery production (e.g. construction machinery and agricultural equipment, some branches of stationary power drive production, electronic controllers for machine tools, etc).

R&D, product design and engineering capabilities upgrading in offshore locations is an extremely dynamic and important aspect of the overall upgrading process. The key here is the need to adapt existing products, developed in the home market, to the specific

¹¹ Herrigel et al 2013, Speed 2007, Jürgens & Krzywdzinski 2012

¹² Herrigel et al 2013

¹³ Herrigel et al 2013

conditions of the emerging market. Increasingly important, especially in big Brics markets, is the need to develop original products tailored specifically for that home market¹⁴. In both cases, pressure to improve the local engineering competence of subsidiary operations intensifies. Home country engineers do not understand intricate foreign customer desires or product usage idiosyncracies. Nor can they easily identify or understand the constraints on product design generated by host country regulations and standards, which apply not only to the product being designed, but also to the materials that are used to make the product. Use of local engineers for these tasks is increasingly inescapable. Firms in the automobile supply chain as well as in the machinery industry are all developing R&D capacity in large emerging markets, in particular China, to enable them to cope with these challenges.

For the most part, the R&D competence being developed in emerging market locations is focused on applied operations: testing locally generated designs, exploring the possibilities of local materials, re-engineering components or manufacturing techniques developed in the home market for use under the different emerging market cost and material conditions. MNC machinery producers and automobile suppliers, above all, develop local R&D capacity with this character. One German drive train technology MNC created a central R&D center in Shanghai (with over 200, mostly Chinese, engineers), which worked on the issues outlined above, always in intimate contact with engineers in the firm's local Chinese production facilities. Engineers in the Shanghai R&D center, in turn, were in continuous contact with the R&D staff located back in the MNC central operations in southern Germany. Central R&D provided more foundational design input and also served as a clearinghouse for design information that the firm's other global R&D operations and production subsidiaries generated.

We found similar R&D arrangements at firms manufacturing computer numerical controllers, stationary drives, hydro-electric turbines, high speed rail drives, construction equipment and a wide array of automobile components. This general division of labor between central and local R&D, moreover, appears to be characteristic of both German and US manufacturing MNCs. Japanese (and Korean) firms tend to centralize R&D far more in the home market and rely on expatriate engineers in offshore locations to achieve adaptations.¹⁵

It is important to note here a significant difference between German MNC subsidiaries in central Europe (or US subsidiaries in Mexico) and their operation in Brics. In the former cases, off shore subsidiaries are to a great extent integrated into the MNC's home market production operations. As a result, virtually all of the local adaptation engineering that dominates R&D work in a place like China is absent in, eg German subsidiaries in Central Europe. This does not mean that central European subsidiaries have less engineering or R&D competence than subsidiaries in farther flung markets. Instead, it means that locations are divided between dedicated production facilities (where there are applied engineers) and locations with responsibility for product development, where

¹⁴ Brandt & Thun 2010

¹⁵ Speed 2009, but see also Buckley & Horn 2009 for a differentiated account

genuine R&D takes place alongside application engineering.

The pattern in central Europe in this way resembles the kind of pattern that exists between plants within the German home market. Production facilities compete for competence among sister plants making the same product. The winners gain product development responsibility for specific customers while the losers assume a dependent and more production focused relationship to them. These intra-firm competitive dynamics characterize competence allocation throughout the European operations of German automobile OEMs and first and second tier suppliers. Central European plants, especially in the last decade, have frequently succeeded in winning product design responsibility. For example, one Polish subsidiary of a German front end component manufacturer we studied won a company wide competition for global product development responsibility for Opel, one of the German company's most important customers. Another example from our research: Responsibility for global small torque drive train development for the south German Drive Train supplier mentioned earlier is currently located in the firm's Hungarian facility. In both cases, these facilities have had to develop significant R&D competence for new product design. Central European engineers continue to work closely with German central R&D engineers, but the division of labor is more subtle and interpenetrated. Central European locations with product development expertise can have monopolies within the MNC on product specific forms of knowledge. Similar allocation of competences have been slower to emerge among US and Mexican production locations, but they are increasingly common—particularly outside of the automobile industry.¹⁶

When both forms of offshore R&D expansion are taken together, it is no wonder that expenditures by developed country overseas facilities have expanded very significantly in the last decade. The US has been the global leader in industrial R&D since WWII. The amount of R&D that US MNC manufacturers perform outside of the US has been steadily increasing. In 1999, US MNCs spent 12.6% of total R&D expenditures outside the US. By 2008, that percentage of offshore R&D had increased to 15.7% (about \$37.0 billion).¹⁷ Within that shift toward offshore R&D, there has also been a pronounced shift away from developed to developing market R&D investment. According to the US Bureau of Economic Activity's Science and Engineering Indicators report from 2012:

“The combined share of Europe, Canada, and Japan as hosts of R&D by U.S.-owned foreign affiliates declined from about 90% in the mid- and late 1990s to around 80% since 2006. On the other hand, the share of R&D performed by Asia- located affiliates (other than in Japan) increased from about 5% to 14% from 1997 to 2008. In particular, the share of U.S.-owned affiliates' R&D performed in China, South Korea, Singapore, and India rose from a half percentage point or less in 1997 to 4% for China, just under 3% for South Korea, and just under 2% each for Singapore and India in 2008.”¹⁸

Growth in offshore German MNC R&D has been similarly recomposed. Between 1995

¹⁶ Thompson 2012

¹⁷ US Bureau of Economic Activity, 2012 p 4-26.

¹⁸ US Bureau of Economic Activity, 2012 p 4-27.

and 2005, German MNCs opened as many offshore R&D sites as they had in the last 50 years combined.¹⁹ While offshore growth was most strong in North America and Europe (including central Europe), the growth of R&D units in Asia increased steeply as well. 10.3% of all overseas R&D units established in the Machinery industry between 1995 and 2005 were in Asia. Growth since then has accelerated. By 2009, overseas affiliates of all German MNCs had spent €11.2 billion on R&D activities overseas, about 27.2% of total R&D outlays. The Machinery industry invested 19.6% of total outlays in 2009 overseas, while the Motor vehicle industry invested 18.2% abroad in that year.²⁰

B) Consequences for developed country manufacturers, in particular for research and innovation strategy

These developments abroad have significantly affected developed country MNC internal governance processes and home country operations. From a governance perspective, as we noted briefly above, MNCs are developing global monitoring and exchange systems that both support disparate local technical and organizational experimentation processes and capture and distribute promising developments from those locations to other MNC operations that could profit from them. Corporate production systems facilitate these learning and innovation oriented governance practices. We have described these new governance processes in several other articles.²¹ Here we will focus attention primarily on the way in which the new governance procedures interact with the shift to “produce where you sell” outlined above to create a variety of new actors and recompose MNC home locations.

MNC home locations are being recomposed in three significant ways. First, home location centrality for future oriented R&D is both solidifying and expanding in scope. It is solidifying because home locations, especially in the US and Germany, have a comparative advantage for engineering talent and contact with research and development infrastructure and support: Universities and polytechnics, pools of highly qualified engineering school graduates, and talented clusters of dedicated research firms and consultancies. More actively, the role of home market product development research is also expanding as researchers need to take into account the rapid development and proliferation of product applications and modifications occurring across an unprecedented array of global markets. Central R&D participates at various levels in product development teams, and collaborates with engineering and manufacturing counterparts in all global locations. As R&D, design and product development efforts expand in offshore affiliates, the qualitative and quantitative demands on central competence increase correspondingly. Firms need to expand their engineering workforce to accommodate this new demand.

¹⁹ Ambos, 2005 p 401.

²⁰ Neukirchner 2012; Kladroba 2011 Tabelle 24

²¹ Herrigel et al 2013; Herrigel 2013

Second, driven by the new internal governance practices noted in the last section, home country R&D competence is drawn in to a support role for far flung MNC technical experimentation processes. Engineers in subsidiaries all over the world call on home country competence for aid and input in their local experiments. Manufacturing MNCs have, as a result, created globally mobile cohorts of engineers and technicians, based in the home locations with close ties to R&D engineering expertise, who both cooperate with and monitor the progress and needs of subsidiary product development processes. Many German machinery and automobile component producers, for example, have created continuous improvement teams (CITs) who travel across all MNC affiliates spreading the gospel of their company's corporate production system. CIT's encourage teams to experiment locally, while at the same time they offer suggestions for improvement. CITs facilitate the diffusion of common language and practice as well as the flow of knowledge and innovation throughout the enterprise. In other words, they foster the dynamic of local discretion, hybridization and learning described earlier. (see SEW article). US-American firms have created similar entities. Significantly, these roles are growing *along with* the expansion of competence and production sophistication abroad.²²

At the moment, such teams are composed primarily of home country technicians and engineers because they have most familiarity with the MNCs corporate production practices and the greatest overview of MNC global operations. Effectively, the expansion of these sorts of roles increases home country demand for production engineers and technicians. There is no reason, in principle, why such roles have to be performed only by home country personnel, and, indeed, over time MNCs may seek to internationalize these cohorts. There is already evidence of mixed nationality CITs using European and North American personnel in our target sectors. Global suppliers and machinery producers, in particular cultivate international teams. The German producer of hydro-electric turbines in our research sample, for example, had advanced very far in this regard. Since much of global demand for its turbines has existed in emerging markets for nearly two decades, the company has developed significant offshore engineering and production expertise in its emerging market affiliates. In particular, its Brazilian operations have been very successful in Latin America. As demand for hydro-electric complexes is now shifting to China and elsewhere in Asia (and Africa), the company has incorporated several highly skilled Brazilian engineers and technicians into its hydro divisions CITs.

There is broad statistical support for the trends toward increased demand for engineers and technicians in the automotive, machinery, electro-mechanical and components sectors²³ Although the trends are similar in the US and Europe, Autor finds that European demand is slightly stronger than in the US, perhaps because of the relatively higher weight of manufacturing in the European economy (Autor table)

²² see Herrigel 2013 for a fuller discussion

²³ Alphametrics 2009 page 56 figure 9

The third recomposition dynamic in manufacturing MNC home locations involves direct production operations. On the whole, manufacturing competence and capacity development in emerging markets has NOT resulted in a loss of either competence or capacity in home market locations.²⁴ Manufacturing employment in developed markets has been declining, but this seems to be attributable to factors other than the expansion of MNC FDI offshore.²⁵ As Dorn and others have shown, the bulk of manufacturing employment decline in the US has come from two major factors: First, sectors that compete directly with low cost imports, especially those coming from China, have been unable to remain competitive and have sustained severe employment losses. These are largely lower tech industries, such as clothing, furniture making, and other lower value added segments of a variety of industries. A second significant factor in the shift in manufacturing employment in the United States, and to a significant extent in Germany as well has been the continuous rise manufacturing productivity. The diffusion of lean production practices, coupled with the development of corporate production systems and automation has elevated manufacturing rates of productivity well above the rate of growth productivity in the economy as a whole²⁶. There is some debate, especially in the United States, on how much low cost inputs, traveling along transnational supply networks, have contributed to productivity increases in manufacturing. Surely it has had an effect, perhaps more in the US than in Europe.²⁷ Intermediate inputs in the US come significantly from lower wage locations, especially China, while intermediate inputs in Europe often tend to come from Europe.²⁸ In any case, new studies show that indigenous improvements have been significant. And many of the developments discussed in this paper that follow from the growth of emerging economy domestic markets auger against the continued increase of foreign sourced componentry in the long term.²⁹

Rather than fearing for the loss of developed economy manufacturing, current developments point to the retention, recomposition and even upgrading of core manufacturing sectors, in particular the ones dealt with in this report (automobiles, machinery, components, electro-mechanical machinery). The key here is that the same competition driven “produce where you sell” logic that leads firms to expand their production and development operations abroad also leads them to *retain and upgrade production and development competences at home*. Home country locations need to adapt their products and designs to local regulations, standards and the idiosyncracies of consumer taste and product usage, just as affiliates abroad do. Developed country firms require sophisticated and flexible manufacturing operations in their home regional

²⁴ European Commission 2011

²⁵ Dorn et al 2011, Ebenstein et al 2011, Harrison & McMillan 2011, Spence & Hlatshwayo 2011

²⁶ Slaughter 2012, McKinsey Operations Practice 2012, The Manufacturing Institute 2009

²⁷ Mandel & Housman 2011

²⁸ European Commission 2011

²⁹ Harrison & McMillan 2011, Ebenstein et al 2011, Slaughter 2012, McKinsey Operations Practice 2012

complexes in order to competitively serve the markets that are located there. Developed country manufacturing markets are growing more slowly than developing country markets. But they are still growing, and, moreover, the character of demand is extremely sophisticated. This stems in part from the advanced and cosmopolitan consumers in these markets. But it also is driven by the fact that firms can only achieve growth in these nearly saturated contexts through innovation. Firms need to define new consumer desires by pushing the technological boundaries of their products.

If one combines the reality of innovation driven manufacturing growth with the enhanced role of R&D in manufacturing MNC home operations due to the diffusion of “produce where you sell” strategies abroad, there are a number of consequences for production organization and skill development in manufacturing economies like Germany and the United States. Three seem most significant in the context of this report.

First, since all signs suggest that competition in developed country markets will become more not less innovation intensive, the productivity enhancing techniques that have driven production organization in the last decade are likely only to intensify. This means that lean forms of organization, continuous improvement, low levels of vertical integration and high levels of automation will continue to define developed market manufacturing best practice. Manufacturing facilities need to prioritize flexibility, low cost and high quality in the context of ever shortening product life cycles and expanding product variety. This will constrain the growth of manufacturing workforces. But it will also place great emphasis on the quality of manufacturing workers that remain in production. Manufacturing personnel has to be skilled, capable of problem solving, able to embrace new tasks and be willing to receive on-going training for eventual new roles.³⁰

Second, and in the same direction, because home country R&D operations have expanded, the need for home location prototyping, small batch and quick turnaround manufacturing capacity has expanded accordingly. This further increases the demand for skilled production labor and technicians.

Third, and perhaps most interestingly, the above developments create intense pressure on in-house capacity within MNC home manufacturing plants. Highly skilled labor (in R&D and production) and expensive automation equipment means that firms want to produce only the most high value added items in-house and do not want to devote capacity to older items, even when those items are headed for home country markets. Moreover, given the speed of product life cycle turnover and the heterogeneity and complexity of global new product developments being processed within a home market plant, the time separating new and old products can be short. This makes it difficult for firms to turn to offshore low cost suppliers, including those in nearby developing markets such as central Europe for German or Mexico for US producers. Production flow, product quality and time to delivery needs to be maintained.

³⁰ EIU 2011; Graham 2010; The Manufacturing Institute 2012

This is creating demand for highly flexible manufacturing suppliers located close to developed country manufacturing MNC home plants who can take over mature process capacity and free up in house manufacturing capacity. Somewhat paradoxically, but still very significantly, in this way a secondary sector of component and capacity sub-suppliers is emerging *in developed locations* while at the same time there is corresponding decline in the use of offshore (eastern European, Mexican and Chinese) suppliers for basic manufacturing processes. The old segmentation lines dividing sophisticated producers in developed economies from low-wage/low-sophistication suppliers in developing economies that emerged in the last twenty years during the peak of offshore outsourcing are in this way weakening. Many offshore (eg.: Chinese) suppliers are turning inward, becoming more sophisticated and seeking domestic customers. Others in Poland or Mexico have become producers of their own products and compete as first tier or second tier suppliers and, as a result, are no longer interested in capacity sub-contracting. At home, by contrast, a new segmentation between highly flexible manufacturing integrated into product development processes and capacity suppliers increasingly (re)-located in home market locations seems to be emerging.³¹

To date, evidence for this latter shift toward a new segmentation is largely anecdotal, but managers in both the United States and Germany emphasize its significance. There is great demand for highly sophisticated, low cost suppliers who excel at quick ramp up, rapid turn, mixed batch size production. They can be understood neither as precarious firms or labor, nor as solid participants in the core manufacturing institutions in either the US or Germany. Many of the new suppliers are non-union employers and not members of employer associations. They employ older skilled workers, let go from higher paying core manufacturing employers, as well as skilled immigrant workers willing to work a pay levels beneath those in the core sector. These emerging suppliers constitute new terrain in the future of developed economy advanced manufacturing.

C.: Implications for developed country research and innovation policies

There are three significant areas for public policy action in the context of the developments that have been outlined in this report.

First, it is clear that shifting global MNC R&D and production strategies are enhancing the significance of engineers and technicians in home country locations. The importance of home country R&D is being expanded as it must engage in product development and support for development and adaptation processes across all MNC affiliates, including those in large emerging market economies, such as China. Existing shifts in labor market demand suggest that the trend has existed for the last decade, but developments in emerging markets suggest that trends are accelerating.

All of this places great weight on the capacity of existing engineering training regimes to produce needed manpower and avoid bottlenecks. Germany is in a stronger position than

³¹ for an extended discussion, see Herrigel 2013

the US in this regard, as the country has placed great emphasis on engineering education and research.³² Support for R&D and for engineering education in the US is high, but its relative position has declined. In large part, this decline comes from intensified German and Chinese resource commitment to R&D.³³

If there is a vulnerability in the German orientation to engineering training, it would come from an over fixation on engineering training in high technology areas of engineering (electronics, biotechnology, energy) and a resulting neglect of the (still highly sophisticated) bread and butter specialties in mechanical engineering, informatics, materials science, mechatronics that continue to be central for the competitiveness of automobile, machinery, electro-mechanical and component producers.³⁴ This danger is if anything even more extreme in the US, where there has been more popular and political pessimism about the future of manufacturing, especially in “traditional” or “old line areas” like those that are the focus of this report. Emphasis on skill upgrading and the enhancement of engineering training has been a central focus of manufacturing industry lobbying in the United States³⁵.

In many ways the dynamics that this report has described are “market” driven, in the sense that developed country MNCs are adopting the described strategies in response to developments in their markets and not at the immediate behest of government policy. This is not to say that government policy could not be helpful in the process of recomposition that has been described. Since all developed country manufacturing MNCs are struggling to make their offshore operations competitive, it is reasonable to assume that not all will succeed. Success ultimately depends on three interdependent functions: a.) the development of flexible operations and innovative products in emerging markets; b.) the development of effective global intra-firm governance structures and new internal firm players, such as CITs, that carry and distribute innovation and best practice within the global firm; and c.) effective home country R&D new product development and global application support services that contribute to the continued long term competitiveness of the firm. Home country public policy can do little to directly influence the competitiveness of MNC products in emerging markets. But it is possible for public support to encourage the development of the other two functions. In particular, public policy can support closer relations between MNC manufacturers and training institutions so that the appropriate forms of manpower are being generated.

There is a debate, particularly in the US, about how significant R&D tax policy is as a vehicle for this kind of support.³⁶ Many emerging economies, especially China, India and Russia, have strongly subsidized the development of their domestic R&D capability.

³² US Bureau of Economic Activity 2011

³³ Tyson and Linden 2012, Waldmeir 2013

³⁴ Hirsch-Kreinsen & Westkaemper 2010, Auer 2005, Rollwagen & Renkin 2012.

³⁵ The Manufacturing Institute 2012, Lombardi 2011, Spence & Hlatshwayo 2011, Slaughter 2012; Boston Consulting Group 2011

³⁶ Tyson and Linden 2012

This is also true of powerful European economies, notably Germany. The more sophisticated these alternative centers of R&D become, the more attractive it becomes to manufacturing MNCs to shift future oriented R&D from their home locations to these alternative centers. In the long term, the threat is that the comparative advantage of the home country research and development infrastructures will weaken relative to the emergent newcomers. Manufacturing MNCs could in this fashion potentially allow the “home” location for strategic R&D and support to drift away from the MNCs traditional home location.

R&D tax credits have been pushed as a policy to ward off this sort of migration³⁷. Surely providing large manufacturing MNCs with tax incentives to engage in higher levels of R&D in their home markets will have some effect. But clearly in the absence of public support for the maintenance of a public research and training infrastructure, no level of tax incentives will cause manufacturing MNCs under constant innovation driven competitive pressure to keep their strategic research operations in an uncompetitive public research environment. The pull of continued sophisticated demand in home markets will in any case work to retain some element of “produce where you sell” driven design and production integration.

Finally, the dynamic quality of the current situation, in particular the way in which continuous innovation strategies are generating new roles both within and outside of manufacturing MNCs, poses distinctive challenges for public labor market and training policies. Innovation driven flexibility and role recomposition invariably cause disruption in the individual careers of even the most skilled engineers and technicians. Technological advances challenge working professionals to keep up to date, while innovation induced firm re-orientation can cause highly skilled engineers to suddenly look for another employer. This kind of turbulence can be to a certain extent accommodated by an appropriately robust infrastructure for retraining and job re-allocation. This kind of mechanism, for example, in the manner of Danish Flexicurity policies, would most optimally involve stakeholder organizations—professional and trade union organizations representing engineers and skilled workers and technicians, regional and national employers associations, and training institutions at all levels—in appropriate retraining and reallocation measures.³⁸

³⁷ Tyson & Linden 2012

³⁸ Kristensen & Lilja 2010; Sabel 2012

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Tables

Table 1:

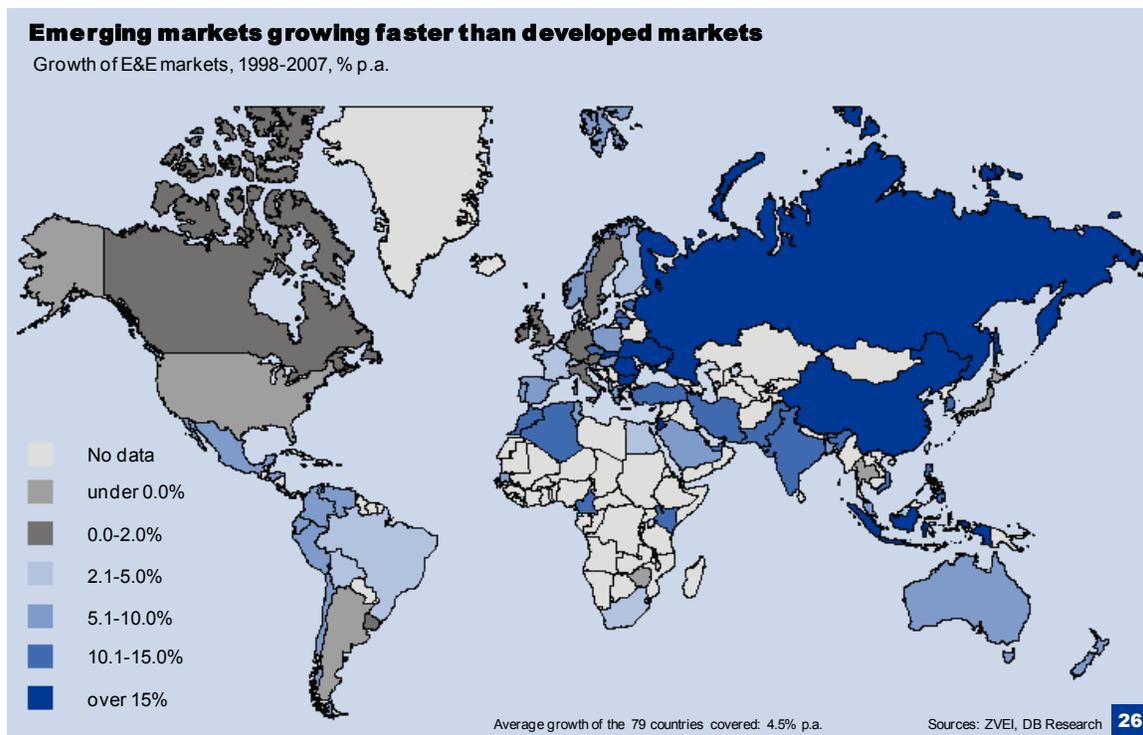
Growth and price forecasts

2010-2015

	2010e	2011f	2012f	2013f	2014f	2015f
Real GDP growth (PPP exchange rates)						
World	4.9	4.1	4.2	4.3	4.3	4.3
OECD	2.9	2.2	2.3	2.3	2.4	2.5
Non-OECD	7.4	6.5	6.5	6.4	6.5	6.5
Real GDP growth (market exchange rates)						
World	3.8	2.9	3.2	3.2	3.1	3.2
North America	2.9	2.4	2.5	2.5	2.5	2.6
Western Europe	2.0	2.1	1.6	1.9	1.7	1.7
Asia & Australasia (including Japan)	6.5	3.8	5.1	4.5	4.4	4.5

Source: Economist Intelligence Unit 2011

Table 2:



Source: Rollwagen & Ranik

Table 3:
Emerging Market Share of Global Passenger Car Demand

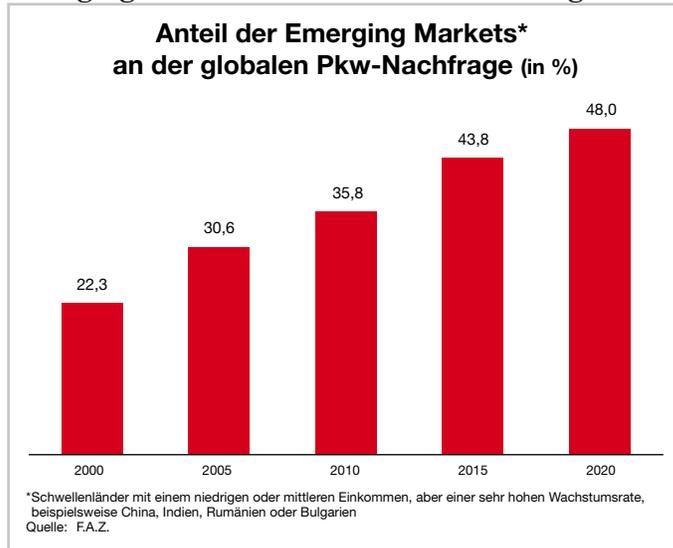
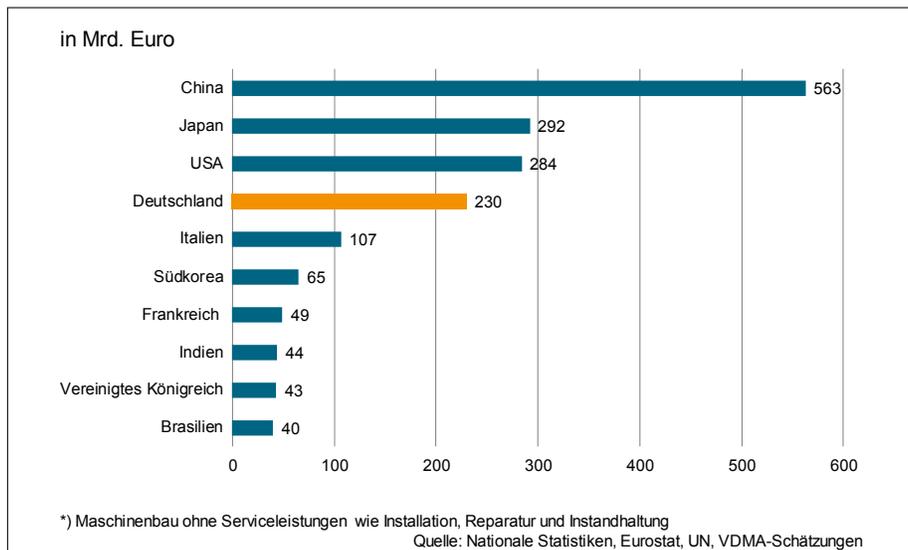


Table 4:

Volkswirtschaft und Statistik

**Weltmaschinenumsatz* 2011
TOP-10-Länder-Ranking**

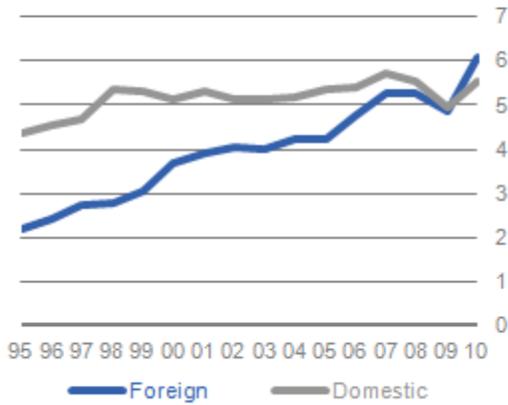


Source: VDMA 2011

Table 5:

Foreign output higher than domestic production

Cars produced by German automakers (million)



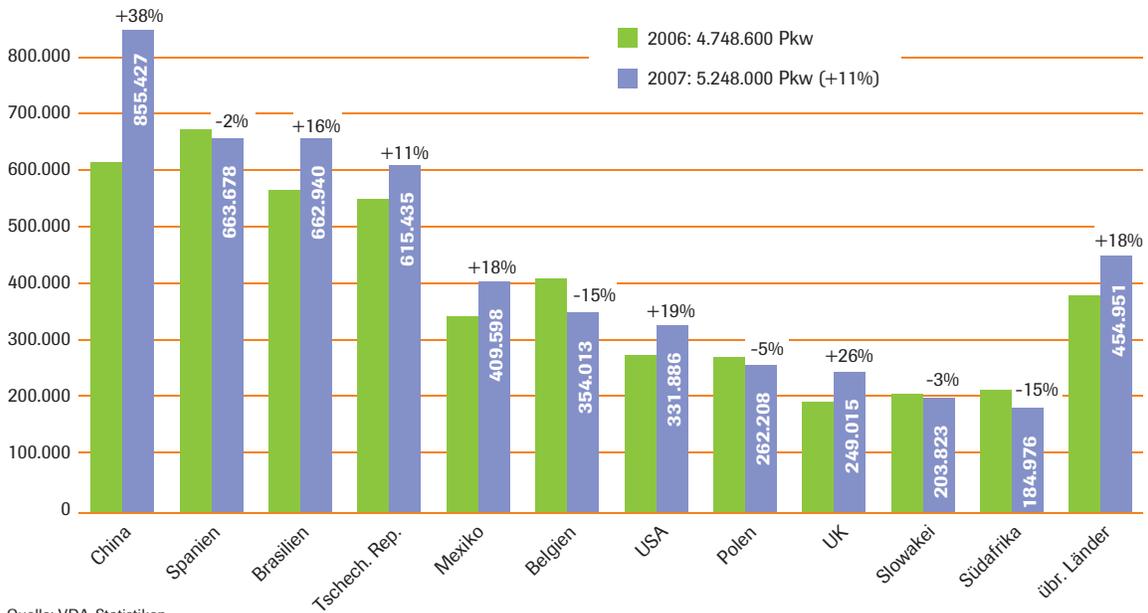
Source: VDA

Source: VDA Jahresbericht 2011

Table 6:

Auslandsproduktion von deutschen Pkw nach Ländern 2007

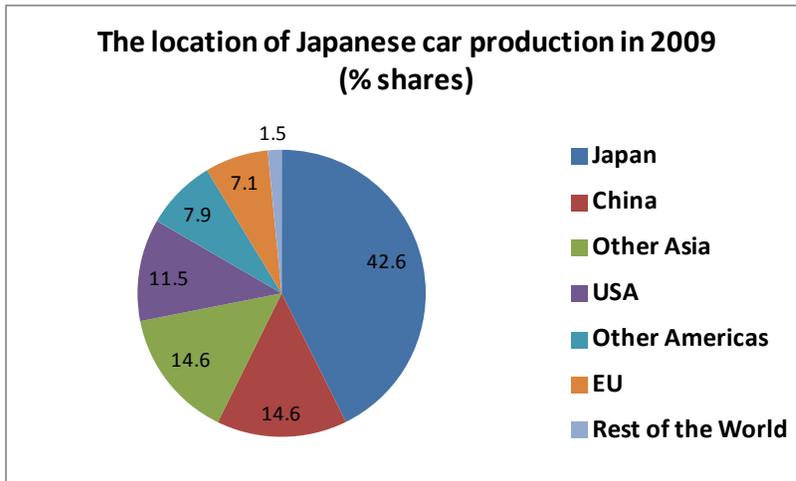
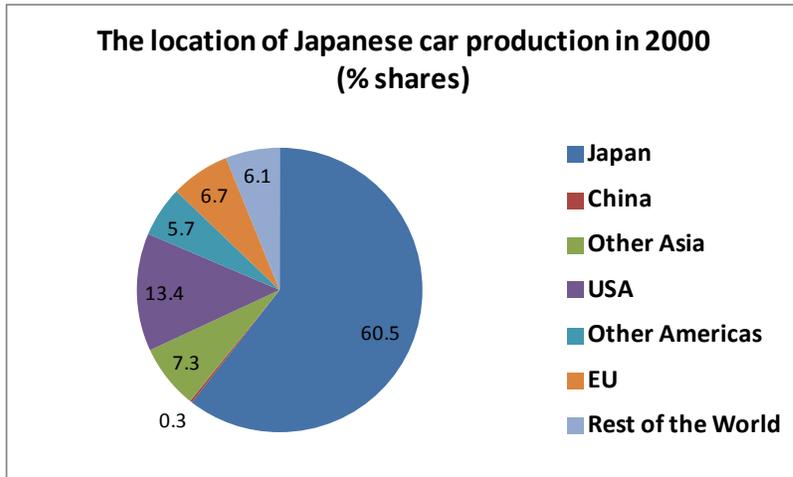
In Einheiten



Quelle: VDA-Statistiken

Source: VDA Jahresbericht 2008

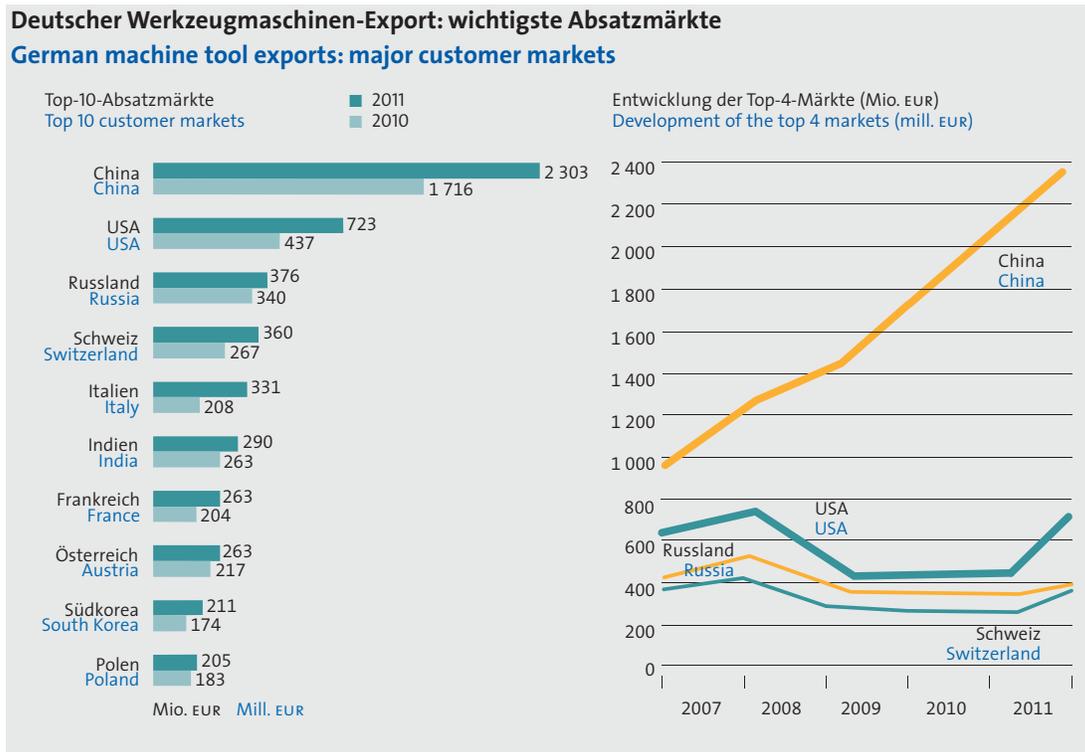
Table 7:



Source: The International Organisation of Motor Vehicle Manufacturers

Source: OECD. 2011. "Recent Developments in the Automobile Industry."

Table 8:



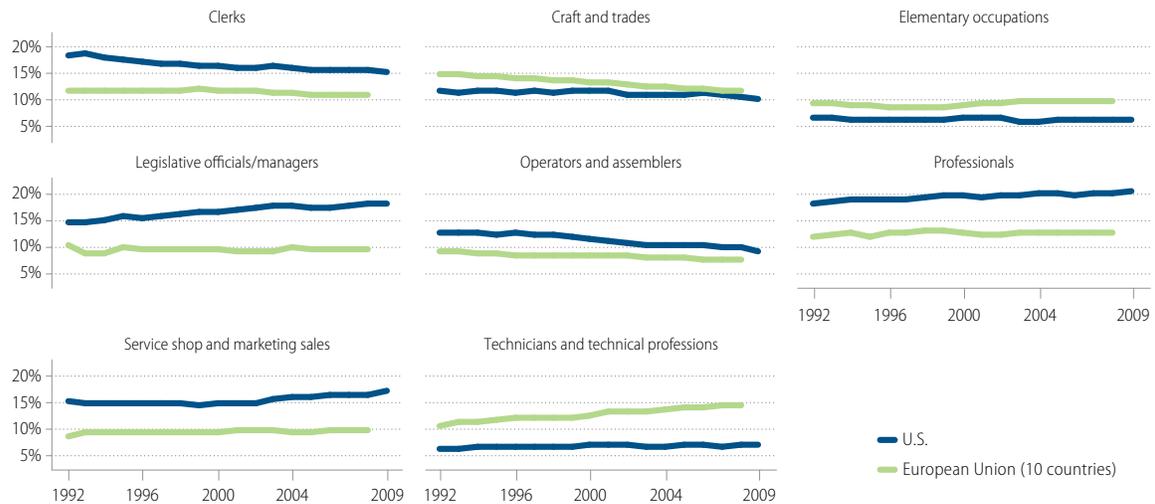
Source: VDMA 2012

Table 9

FIGURE 5A

United States and European Union occupation percentages, age 39 or below

Occupational percentage

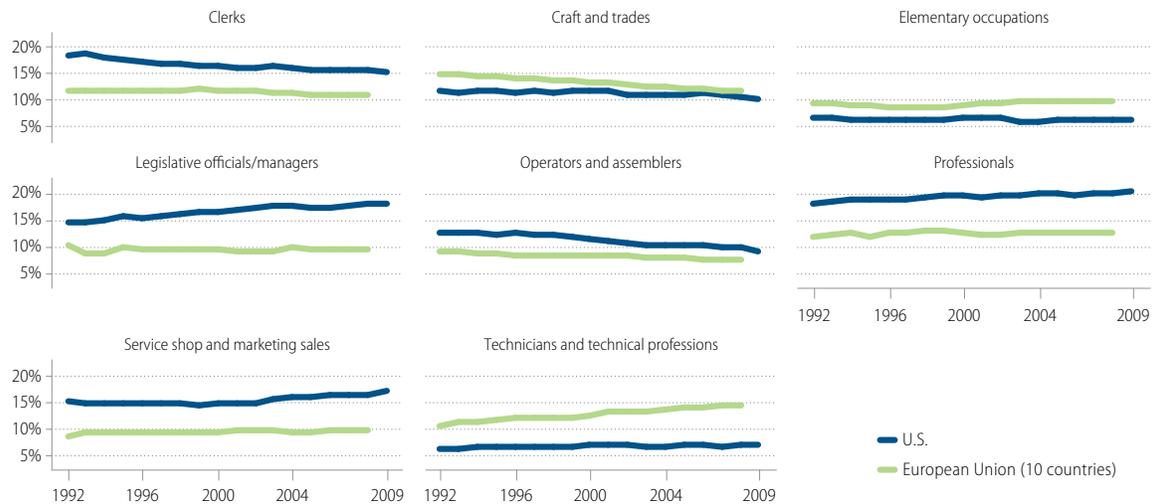


Source: The Eurostat data are based on the harmonized European Labor Force survey, and are available for download at www.eurostat.org. The ten countries included in the series in the paper are Denmark, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, and the United Kingdom. The Eurostat data include many additional EU countries, but not on a consistent basis for this full time interval. The series presented in Figures 4a and 4b are weighted averages of occupational shares across these ten countries, where weights are proportional to the average share of EU employment in each country over the sample period. The Eurostat data include workers ages 15-59 while the U.S. sample includes workers 16-64.

FIGURE 5B

United States and European Union occupation percentages, age 40 or above

Occupational percentage



Source: The Eurostat data are based on the harmonized European Labor Force survey, and are available for download at www.eurostat.org. The ten countries included in the series in the paper are Denmark, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, and the United Kingdom. The Eurostat data include many additional EU countries, but not on a consistent basis for this full time interval. The series presented in Figures 4a and 4b are weighted averages of occupational shares across these ten countries, where weights are proportional to the average share of EU employment in each country over the sample period. The Eurostat data include workers ages 15-59 while the U.S. sample includes workers 16-64.

Source: Autor 2010 p17