Jochem, Patrick; Schleich, Joachim

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Working Paper Sustainability and Innovation
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Patrick Jochem
Joachim Schleich

Exploring the factors driving automotive exports in OECD countries

Fraunhofer ISI

Abstract

Based on data for eight OECD countries this paper empirically explores the factors driving exports in the automotive sector between 1991 and 2008. The factors considered explicitly account for possible lead market effects which have recently been identified in the literature as relevant factors in studying the export potentials of certain technologies. Econometric results suggest that exports in the automotive sector are positively related to the general strength of a country in terms of exports, to higher GDP per capita and to a lower labour cost share in the automotive sector. However, domestic market size and R&D in the automotive sector appear to have no effect on exports. Hence, the results provide only limited rationale for policy intervention.

Keywords

Lead markets, export potentials, automotive industry

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1 Introduction

In a globalised world, inventing and producing internationally-traded products promises to be profitable at a much faster rate than in the past. At the same time, however, globalisation challenges the associated competitive advantage of companies and industries. Compared to the beginning of the last century, successful innovations can now benefit from a much larger market (Fagerberg 2002) due to technological progress in telecommunication and information technologies. Innovations in globally-traded products tend to follow a typical pattern: Products are invented in one country and usually first sold to domestic customers. Economies of scale help to lower production costs and open up markets abroad. Eventually, companies in other countries will follow the first movers and produce and export the same products or varieties thereof. Schumpeter (2004) already pointed out that the profits of first movers with successful innovations are usually high, but he also indicated the risks of considerably lower margins in developed markets. In addition, Schumpeter underlines that the increasing competition between countries and companies in the international context leads to a growing pressure on developed countries to continuously innovate. This might be the main reason why industrialised countries specialise in particular products and technologies. Cantwell (2005), for example, identifies three national clusters for a group of industrialised countries: Countries like the UK and the US are in the first cluster and focus on highly complex products (e.g. professional and scientific instruments, office equipment and computing); countries like Germany and Switzerland are in the second cluster and tend to specialise in somewhat less complex products (e.g. chemicals, metal products and motor vehicles) while specialisation in France and Sweden, which belong to the third cluster, is rather coincidental and primarily due to historical, geographical, or cultural causes.

As countries typically benefit from hosting the development and marketing of new products and technologies, the differences in countries' ability to do so have been the focus of academics and policymakers for some time (Fagerberg 1996; Treubal 1975; Krugman 1979; Porter 1990). From a policy and business perspective, the question arises to which extent regulation and other country-specific factors may contribute to a country becoming a "first-mover" or a "lead market". This lead market concept has recently been developed in the academic literature of business economics (Meyer-Krahmer 2004; Beise 2001 and 2004; Beise and Rennings 2005; Walz 2006). The lead market literature identifies a wide range of factors which includes, besides typical cost

advantages, also demand conditions like the size of the domestic market or characteristics of domestic consumers, the general export orientation of countries or innovation friendliness (Meyer-Krahmer 2004; Beise 2004). As a result, the lead market concept foresees an active role for public policy in creating favourable framework conditions which has been quickly recognised by policymakers at the national and international level in fostering innovation policy. So far, the existing literature on lead markets is primarily based on qualitative analyses for specific case studies (e.g. Jacob et al. 2005; Beise 2004; Beise and Cleff 2004; Beise and Rennings 2005).

In this paper, we first show how the lead market concept is embedded in the various economic theories of international trade. We then econometrically analyse the relevance of factors determining the export performance of OECD member states in the automotive market, drawing on (overlapping) concepts from traditional and new economic trade theory and specifically allowing for "lead market" factors. Hence, our analysis may be interpreted as a first attempt to econometrically assess the contribution of the lead market concept in explaining countries' export performance. While the seminal work on lead markets focuses on particular products or technologies, we take a broader perspective and consider an entire sector (the automotive sector), thereby capturing spillover effects on component suppliers. Further, we implicitly allow for lead market factors to be relevant not only for the original product, but also for the related product varieties in developed markets (such as smaller cars, luxury cars, more reliable cars etc.).

The remainder of the paper is organised as follows. In Section 2 we provide a brief overview of the international trade theory and the lead market theory. Then we present the variables and data used in the econometric analysis. Estimation results appear in Section 4. The concluding section summarises the main findings.

2 Overview of international trade theory and the lead market approach

International trade theory

The span of classical international trade theory reaches from early theories about protectionism (Mercantilists) through the development of the principle of absolute cost advantage by Adam Smith to the theory of comparative cost

advantages and productivity by David Ricardo. While, for Smith, trade was only beneficial if two countries had an absolute cost advantage in the production of different goods (on which the country should concentrate its production resources), Ricardo shows that even a comparative cost advantage in production is sufficient for both trading countries to benefit from international trade. Ricardo's work also formed the basis for the Neoclassical Trade Theory, which explains the patterns of trade and factor remuneration via differences in factor endowment, in technology (factor productivity) and in preferences across countries.[1] Samuelson's mathematical formulation of a two-country, two-sector, two-factor model became the workhorse of theoretical and empirical research in explaining factor remuneration and inter-industry trade flows.

New international economics builds on neoclassical trade theory, but includes concepts from the emerging field of industrial organisation. In particular, new international economics studies the impact of market structure, product differentiation or technology development and diffusion on the pattern of trade and regional development. The seminal papers by Krugman (1979, 1981) introduce economies of scale and monopolistic competition[2] and help to explain the empirical phenomenon of the so-called Leontief paradox (Leontief 1953) and rapidly growing intra-industry trade.[3] Together with Helpman and Krugman (1985), these papers initiated a comprehensive empirical research agenda on bilateral trade flows (Prize Committee of the Royal Swedish Academy of Sciences 2008).

Focusing on the patterns of trade over time, New Growth Theory accounts for dynamic comparative advantages (Grossman and Helpman 1994) and combines concepts from the Heckscher-Ohlin theory, the product life cycle model, and spatial economics (differences in policies and regional technological externalities).

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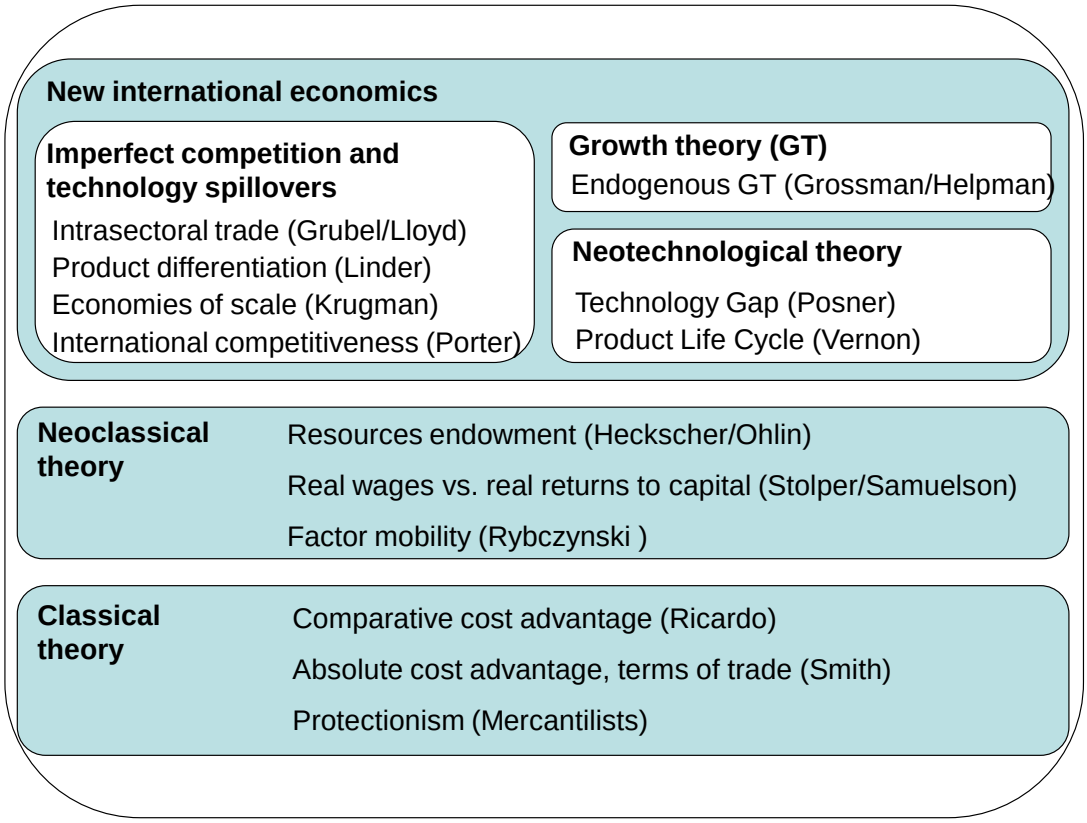
1 For overviews see, for example, Helpman (1999) or Krugman and Obstfeld (2006).

2 The basic concept of monopolistic competition was originally developed by Chamberlin (1933) and later resumed by Dixit and Stiglitz (1977).

3 Based on empirical input-output analyses, Leontief (1953) found that – in contrast to the prediction of the neo-classical Factor Productions Theorem – relatively capital-intensive (i.e. developed) countries import also relatively capital-intensive goods and export relatively labour-intensive goods.

Figure 1: Overview of international trade theories and their key concepts



In conclusion, international trade theory identifies a set of drivers for cross-country inter- and intra-sectoral trade, including differences in technology and factor productivity rates, quantitative and qualitative factor endowment, preferences for domestic and foreign products, market structure, and regional spillovers. Nevertheless, this set of factors is not able to fully explain observed trade patterns and volumes (Helpman 1999).

Lead Market concept

Besides these theories from international trade theory (see overview in Figure 1) the concept of Lead Markets has been developed more recently in business economics and focuses on the export performance of innovative technologies and products (Meyer-Krahmer 2004; Beise 2004; Beise und Rennings 2005). According to the definition adopted by the European Commission (2007) "*A lead market is the market of a product or service in a given geographical area, where the diffusion process of an internationally successful innovation (technological or non-technological) first took off and is sustained and expanded through a*

wide range of different services". Accordingly, a lead market is not necessarily the market or country where a product or technology was first developed or used. For example, the automobile and the fax machine were both invented in Germany, but their first large-scale production took place in the US and Japan, respectively. Hence, a lead market is instead defined by a country's ability to transform inventions into commercially successful products – at home and abroad. Further, lead markets are not confined to the original product or technology, but encompass the entire value chain, including services and component suppliers.

The lead market concept is based, in particular, on two complementary theories within the so-called neo-technological theory: the technology gap theory (a. o. Posner, 1961) and the product life cycle theory (a. o. Vernon 1966; Krugman 1979; Gray 1980; Dollar 1986). The technology gap theory focuses on the supply side and explains differences in national productivity rates by differences in the technology stock across countries. Empirically, technology gaps can largely be explained by differences in expenditures for research and development (e.g. Fagerberg 1987). The product life cycle theory, which highlights the impact of the demand side, was originally developed in business administration (marketing) to study national product markets (Levitt 1965), but has also been further developed in the economics literature, in particular in evolutionary economics within the context of industrial life cycle (Dosi and Nelson 1994). If applied to explain trade flows over time, the product life cycle theory suggests that developed countries first export innovative products to less developed countries. Over time though, less developed countries become more advanced in imitating developed countries and eventually turn into exporters of these products once they have managed to adopt the technology and produce it at lower factor costs (typically labour costs). Hence, developed countries need to innovate continuously if they want to sustain their accustomed levels of exports and incomes. More innovative countries will then also exhibit higher export levels. Product life cycle theory presumes an upward trend in demand during the early stages of a product's implementation. Then demand for these products may decline in the inventor region. However, since the product life cycle approach assumes permanent feedback from customers to producers and a low probability of relocating production (a. o. Pfirrmann 1994; Taylor 1986), it is not able to explain patterns of trade or countries' export performance at a general level.

Conceptual and qualitative empirical research of lead markets identified factors which are considered to positively affect a country's lead market potential.

Meyer-Krahmer (2004) lists the following factors: (1) a national demand situation characterised by high income elasticity and low price elasticity or a high per capita income; (2) a national demand with high quality requirements, great readiness to adopt innovations, curiosity concerning innovations and a high acceptance of technology; (3) favourable conditions allowing for rapid learning by suppliers; (4) authorisation standards that 'set standards' for permit authorisation in other countries (e.g. pharmaceuticals in the US); (5) a functioning system of exploratory marketing (‘lead user’ principles); (6) a specific, problem-driven pressure to innovate; and (7) an open, innovation-oriented regulation and socio-economic environment. Similarly, Beise and Cleff (2004) categorise five groups of determinants, which are largely based on Porter’s (1990) “five main groups of competitive advantages[4] of a country”: (1) “price and cost advantages”; (2) “demand advantage”, implying primarily that domestic consumers motivate companies to produce innovative product designs which might later be adopted by consumers abroad; (3), “transfer advantage”, which refers to the potential of a country’s consumers to act as trendsetters for consumers in other countries; (4) “export advantage” comprised of two factors: the similarity of local market conditions with respect to cultural, social and economic factors (see Vernon 1979) and the sensibility of the domestic market to foreign markets and global challenges or trends (e.g. environmental friendly products); (5) “market structure advantage”, implying that strong domestic competition leads to the higher probability of a company persisting successfully abroad.[5]

To sum up, the lead market concept has high overlaps with different concepts from international economics, but highlights the importance of factors derived from the marketing literature such as “lead users” as well as from the innovation literature, such as “transfer advantage”. Empirically, applications of the lead market concepts consist of qualitative case studies, so far.[6]

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4 Porter and the Lead Market concept interpret competitive advantage according to Cantwell (2005), who defines competitiveness on the country level as “the way in which the pattern of international trade evolves over time to reflect changing patterns of capabilities and hence competitive advantage (what might be thought of as the evolution in the comparative advantage of countries), rather than about the established pattern of comparative advantage which is the usual focus of trade theory.”

5 See also Cantwell (2005) and Fagerberg (1996).

6 Jacob et al. (2005) also analyse the lead and lag market structure for fuel-efficient passenger cars, catalytic converters, fuel cell vehicles, and emission reduction technologies for diesel vehicles.

3 Methodology, variables and data

We consider the automotive sector an appropriate case for empirically analysing the impact of various factors on countries' success in export markets, allowing specifically for lead market factors. The automotive market has been extensively studied in the literature and may be characterised as innovative and trade-intensive (Vickery 1996; Lachenmaier and Woessmann 2004). Further, although the automotive market is a late developer with respect to globalisation (UNCTAD, 1999), it has particularly benefitted from globalisation (Spatz and Nunnenkamp 2002), with production sites in many developed countries and, more recently, also in emerging economies. In many countries, the automotive sector (including component suppliers) is a key sector in terms of employment, innovation and value added. Hence, from a policy as well as from a marketing perspective, the factors driving success in export markets are of interest. For example, politicians' willingness to use tax money to "save" car manufacturers in the US and Europe during the financial and economic crisis, which started in late 2008, reflects the high profile of the automotive sector in society. Current challenges to the sector are driven, among others, by continuing environmental pressure, in particular from climate change, leading to a change in customer demand from powerful and oversized vehicles to more efficient and smaller vehicles, as well as to new driving technologies (e.g. electric vehicles). These developments have led car manufacturers to look for new allies, mergers, and new production sites.

In order to empirically assess the contribution of the lead market concept in explaining countries' export performance, appropriate indicators need to be identified and sufficient data for these indicators needs to be available. In addition, even if sufficiently long time series data was available, many lead market indicators (such as per capita income or population size) do not vary much over time. Hence, the variation in variables in analyses based on time series data for a single country may not allow for meaningful statistical analyses. In comparison, cross-country analyses are likely to suffer from lack of observations (degrees of freedom), since a particular product or technology may not be produced in many countries. This holds in particular if the product or technology is innovation-intensive, which tends to be the case for typical lead market applications. At the same time, cross-country analyses may suffer from the so-called "omitted variable" bias. That is, if relevant variables are not included in the regression equation (e.g. for lack of data) and if these variables are correlated with the included explanatory variables, the estimates of the parameters associated with these variables are biased. In comparison, using

panel data, where data is available for multiple countries for several years, allows controlling for omitted variables that differ between countries, but are constant over time. Similarly, panel data analyses may control for omitted variables that vary over time, but are constant between countries (e.g. Hsiao 2003). Panel data also allow for more degrees of freedom than time series or cross-sectional models. For these reasons, in this paper we apply panel data analysis to econometrically explore factors driving exports in the automotive sector.

Data for our analyses stems from the OECD STAN Industry database. Our sector of interest is classified in the ISIC sector 34 “manufacture of motor vehicles, trailers and semitrailers” which also includes their suppliers.[7] National exports by the automotive sector serve as the dependent variable in the subsequent econometric analysis.[8] Hence, the dependent variable *auto_export* may be interpreted as the realised lead market potential by a particular country in a particular year. The explanatory variables serve as proxies for factors determining exports. In particular, they are supposed to capture the lead market advantages described in Section 2. More specifically, the variable share of labour income in value added (*labourcosts*) is included to reflect cost advantages. The variable total exports of the economy (*economy_export*) is supposed to represent general export advantages of a country, stemming, among others, from spillovers of know-how from export-intensive sectors, or from institutional factors facilitating exports such as trade associations, or the availability of export credits. GDP per capita (*gdp_pc*) and population (*pop*) stand for demand advantages. For example, a high income per capita is supposed to be related to the “lead user” and “trendsetter” potential. A larger population reflects a larger domestic market. Research and development expenditures in the automotive sector[9] within the last three to five years (*rd*) are

7 The classification ISIC (International Standard Industrial Classification) is used in the OECD STAN (STructural ANalysis) database and is initialised by the UNSD. More precisely, we used the classification of the third revision (ISIC Rev. 3).

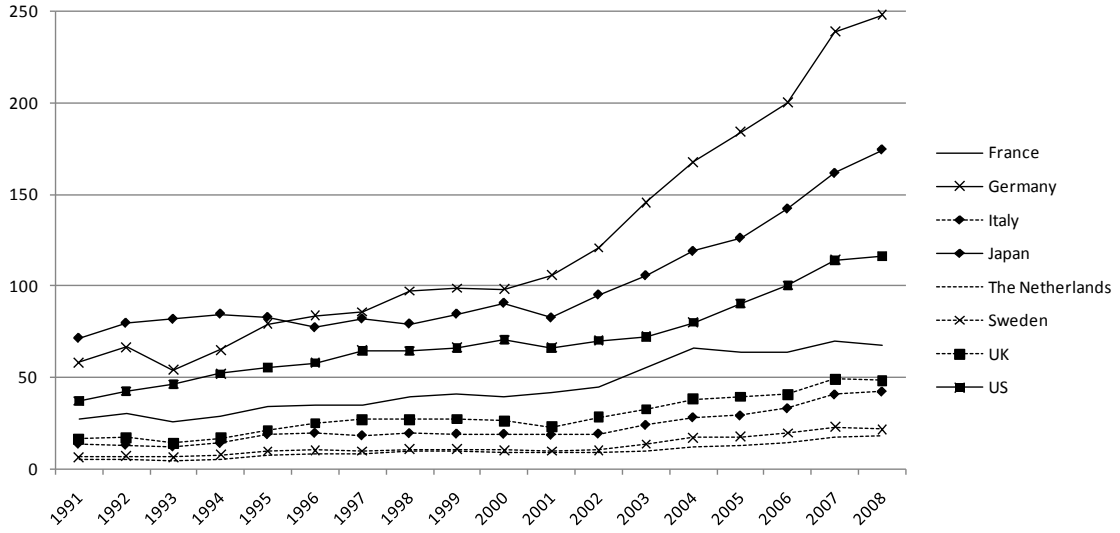
8 This approach is similar to Lachenmaier and Wößmann (2006) who for some industries analysed the impact of innovation on export shares of German companies in different federal states.

9 In the following it should be kept in mind that the STAN Database warns against a comparison of sector specific R&D data due to their different measuring methods. One major difference is the allocation of R&D expenditures to “main activity” in Germany, Italy, Japan, the Netherlands and the US compared to the allocation to “product field” in France, Sweden and UK. Furthermore, the country specific measurement of R&D expenditures in multinational companies is not unambiguous.

assumed to capture effects like rapid learning by suppliers, innovation friendliness or transfer advantages.

Finally, country-specific trend variables are included to model country-specific effects over time.

Figure 2: Development of exports of the automotive sector by country (in current billion US$)



For our regression analyses, data are available for the years 1991 to 2008 from the OECD STAN Industry database for countries with sufficient relevance in the automotive sector: France, Germany, Italy, Japan, the Netherlands, Sweden, the UK and the US. Data availability allows for a balanced panel. Table 1 provides an overview of the variables used and Figure 2 shows the development of the dependent variable *auto_export*. Descriptive statistics along with country-specific details and units can be found in Appendix Table A1. Further, country dummies are included to reflect the effects of country-specific factors on export performance of the automotive sector. To avoid singularity of the regressor matrix, no country dummy was included for the US, which hence serves as the basis. Also, four year dummies are included to capture potential effects of the general economic crises in the early 1990s, of the post 9/11 effects in 2001 and 2002 and of the latest financial crisis in 2008. Finally,

stationary tests for panel data suggest that the dependent variable is trend stationary, a time trend is included.[10]

Table 1: Description and descriptive statistics of variables

Lead Market Factor	Variable Definition	Variable Name	Mean
–	Exports of the automotive sector [billion US$$_{current}$]	*auto_export*	51.5
Export advantage	Export of all sectors in a country [billion US$$_{current}$]	*country_export*	394.4
Demand advantage	Population [thousands]	*pop*	86,058
Demand advantage	GDP per capita [US$$_{current}$]	*gdp_pc*	27,124
Transfer advantage, innovation friendliness	Average annual expenditures for research and development in automotive sector of previous three to five years [millions US$ $_{current}$]	*rd*	4,305
Cost advantage	Share of labour income in value added	*labourcost*	0.67

The regression equation may then be specified as follows (neglecting dummies and time trend):

$$auto\_export_{it} = \beta_1 + \beta_2 economy\_export_{it} + \beta_3 pop_{it} + \beta_4 gdp\_pc_{it} + \beta_5 rd_{it} + \beta_6 labourcost_{it} + \varepsilon_{it} \quad (1)$$

where i is the index for the country and t for time (years). In the actual regression, all variables enter equation (1) in natural logs.[11]

4 Estimation results

We use STATA 11 to estimate equation (1) via the Feasible Generalized Least Square Estimator accounting for heteroskedasticity and for autocorrelation[12]. Estimation results appear in Table 2.[13]

10 Note that the trend variable may also account for inflation, since variables from the OECD STAN database are in nominal terms.

11 The only exception is the variable “share of labour income in value added” – it enters the equation without any transformation.

In terms of goodness of fit, the value for the coefficients of determination (R^2) and the Wald chi square statistics (p<0.001) suggest that the estimated model is capable of explaining a high share of the variation of the dependent variable.

Table 2: Regression results

Dependent variable: *auto_export*			
Variable	**Coefficient**	**SD**	**P-Value**
economy_export	0.336	0.084	0.000
pop	-0.891	0.652	0.172
gdp_pc	0.662	0.296	0.025
rd	0.042	0.065	0.520
labourcost	-1.552	0.716	0.030
Germany	0.036	0.010	0.001
France	0.051	0.020	0.011
Italy	0.013	0.008	0.100
Japan	0.070	0.011	0.000
Netherlands	0.036	0.015	0.021
Sweden	-0.007	0.020	0.744
UK	0.033	0.010	0.001
trend	0.019	0.013	0.158
year1993	-0.115	0.024	0.000
year2001	-0.142	0.026	0.000
year2002	-0.101	0.026	0.000
year2008	-0.028	0.032	0.375
constant	6.830	8.238	0.407
Wald $chi^2(17)$ = 6627.19	Prob > chi^2 = 0.000	Observations = 136	$R^2_{overall}$ = 0.982

Some, but not all estimated coefficients are statistically significant and confirm the hypothesised effects of lead market factors (see Table 2). The parameter estimates associated with economy-wide exports and GDP per capita are

12 Autocorrelation is captured via the Prais-Winsten transformation (Prais and Winsten 1954). The Prais-Winsten estimator is feasible as the number of years is sufficiently high and larger than the number of countries.

13 In general, results are fairly robust to different lag structures for the explanatory variables or to using GDP rather than GDP per capita. Results for other specifications are available from the authors upon request.

statistically significant (at $p<0.05$) and exhibit the expected positive sign. Likewise, the variable "share of labour income in value added" exhibits the expected negative sign and is statistically significant (at $p<0.05$), suggesting that a higher share of labour costs result in lower exports – we interpret this equivalent to higher labour costs and assume a constant autoimmunisation share within the automotive sector for OECD countries. However, neither population nor expenditures for research and development turn out to be statistically significant. Also, while the trend variable is not (but almost) statistically significant at conventional levels, the three of the four year dummies capturing economic downturns are all negative and statistically significant (at $p<$ 0.01). The results for the country dummies suggest that there are significant country-specific effects in most countries which are not captured by the other explanatory variables.

5 Conclusions

After briefly reviewing the main theories of economic trade theory, we have shown how the emerging lead market concept is linked to these theories. Conceptually, the lead market concept draws heavily on the new international trade theory, in particular on the neo-technological theory developed by Posner (1961) and Vernon (1966).

Results from econometrically analysing the relevance of factors determining the export performance of the automotive sector in eight OECD countries support the view that a country's general ability to export, as well as a high GDP per capita and low labour costs, result in higher exports in this sector. Contrary to the suggestions of the lead market concept or the endogenous growth theory, however, sector-specific R&D is not found to have a statistically significant effect on export performance which might be due to the fact that the measuring methods of sector specific R&D expenditures do differ between countries.[14] Thus, our findings provide only limited rationale for policy intervention to

[14] The empirical evidence of the effects of R&D on exports in the literature is rather mixed. Fagerberg (1995) does not find a significant relation between R&D intensities and export performance. Other studies (Lacroix and Scheuer 1976; Magnier and Toujas-Bernate 1994; Soete 1981; Amable and Verspagen 1995; Fagerberg 1996) conclude that the trade performance of a country is positively related to R&D expenditures. Most of these findings, however, are based on bi-variate rather than multivariate analyses. For our data, the Pearson correlation coefficient between *auto_export* and *rd* is 0.89 ($p<0.01$), but the relation is not statistically significant in our multivariate analysis.

increase exports in the automotive sector. These measures should improve the general export performance of a country or lower labour costs.

The relation between government intervention and success in export markets also figures in current debates on the future development of electric vehicles. A move towards electric vehicles implies altering crucial vehicle components. Most prominently, the technologically rather complex combustion engine with its sophisticated gearbox will be replaced by a relatively simple electric motor. A key technological challenge will be to develop a cost-efficient, space-saving battery with high mileage (e.g. Valentine-Urbschat and Bernhart 2009; Kley et al. 2011). These technological innovations may lead some manufacturers and their suppliers to consider relocating production. Policymakers and companies are aware that location decisions may be the determining factor to account for a successful product introduction and hence affect a country's benefits in terms of employment or tax revenues. Our findings for population (market demand advantage) suggest that the size of the domestic market may not be an important lead market factor in the automotive sector. Hence, our findings are not at odds with current policy objectives for relatively small countries like Germany to become a lead market for electric vehicles. However, our results from multivariate analyses also imply that R&D support may not be an effective measure to increase exports.

Our findings should be interpreted carefully, but they also point to avenues for future research. For example, our variable reflecting the impact of domestic demand factors for export performance (population) does not capture demand-related cultural, sociological or psychological factors, which – as pointed out by Gatersleben (2007) – also affect the demand for automobiles. As a consequence, domestic consumers may have a generic preference for domestic rather than for foreign brands. Future research may try to capture these preferences in empirical analyses. Likewise, R&D and its effect on exports is measured at the level of the entire automotive sector, and hence may not adequately reflect effects at the sub-sectoral level, such as the impact of technology-specific support for high-performance batteries for electric vehicles. In addition, the future relevance of R&D for the automotive sector may shift from car manufacturers (combustion engine) to component manufacturers in the mechanical and electrical engineering sectors, further strengthening the position of suppliers (Valentine-Urbschat and Bernhart 2009). Hence, future empirical analyses may have to include automotive-specific R&D in these sectors at home and – in light of continuing globalization – also abroad.

Finally, our findings are specific to the automotive sector and may not be transferrable to other sectors, products or technologies. Hence, similar analyses would be needed to assess and compare the relevance of determinants for countries' export performance and the contribution of the lead market concept for other applications.

References

Amable, Bruno, and Bart Verspagen (1995): The Role of Technology in Market Shares Dynamics, Applied Economics 27(2), 197-204.

Becker, Helmut (2007): Auf Crashkurs, Heidelberg.

Beise, Marian (2004): Lead Markets: Country-specific drivers of the global diffusion of innovations, Research Policy 33, 997-1018.

Beise, Marian (2001): *Lead markets: country-specific success factors of the global diffusion of Innovations*, Heidelberg.

Beise, Marian, and Thomas Cleff (2004): Assessing the lead market potential of countries for innovation projects, Journal of International Management 10(4), 453-477.

Beise, Marian, and Klaus Rennings (2005): Lead Markets for Environmental Innovations: A Framework for Innovation and Environmental Economics, Ecological Economics 52, 5-17.

Chamberlin, Edward H. (1933): The Theory of Monopolistic Competition, Cambridge, MA.

Cantwell, John (2005): Innovation and Competitiveness, in: J. Fagerberg, D.C. Mowery, and R.R. Nelson (Eds): The Oxford Handbook of Innovation, Oxford, 543-567.

Dixit, Avinash K., and Joseph E. Stiglitz (1977): Monopolistic Competition and Optimum Product Diversity, American Economic Review 67, 297-308.

Dollar, David (1986): Technological Innovation, Capital Mobility, and the Product Cycle in North-South Trade. American Economic Review 76 (1), 177-190.

Dosi, Giovanni, and Richard R. Nelson (1994): An introduction to evolutionary theories in economics, Journal of Evolutionary Economics 4, 153-172.

European Commission (2007): A lead market initiative for Europe. Communication from the Council, the European Parliament, the European Economic and Social Committee and the Committee of the regions, COM(2007) 860 final, 21.12.2007, Brussels.

Fagerberg, Jan (2002): Technology-gaps, innovation-diffusion and transformation: an evolutionary interpretation, Research Policy 31(8-9), 1291-1304.

Fagerberg, Jan (1996): Technology and Competitiveness, Oxford Review of Economic Policy 12 (3), 39-51.

Fagerberg, Jan (1995): Is There a Large-country Advantage in High-tech?, INUPI-Working Paper No. 526, Oslo, Norway.

Fagerberg, Jan (1987): A technology gap approach to why growth rates differ, Research Policy 16(2-4), 87-99.

Gatersleben, Birgitta (2007): Affective and symbolic aspects of car use: a review. In: T. Gärling and L. Steg (eds). Threats to the Quality of Urban Life from Car Traffic: Problems, Causes, and Solutions, Elsevier, Amsterdam, Chapter 12, 219-234.

Gray, H. Peter (1980): The Theory of International Trade Among Industrial Nations, Review of World Economics 116(3), 447-470.

Grossman, Gene M., and Elhanan Helpman (1994): Endogenous Innovation in the Theory of Growth, Journal of Economic Perspectives 8(1), 23-44.

Helpman, Elhanan (1999): The Structure of Freight Trade, *Journal of Economic Perspectives* 13(2), 121-144.

Helpman, Elhanan, and Paul R. Krugman (1985): Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy, Cambridge, MA.

Hsiao, Cheng (2003): Analysis of Panel Data, Cambridge University Press, New York, 2nd edition.

Jacob, Klaus, Marian Beise, Juergen Blazejczak, Dietmar Edler, Ruediger Haum, Martin Jänicke, Thomas Loew, Ulrich Petschow, and Klaus Rennings (2005): Lead markets for environmental innovations, Springer, Heidelberg.

Kley, Fabian, Christian Lerch, and David Dallinger (2011): New Business models for electric cars – a holistic approach, Energy Policy 39, 3392-3403.

Krugman, Paul R. (1981): International Trade in the Presence of Product Differentiation, Economies of Scale, and Monopolistic Competition, Journal of International Economics 11, 305-340.

Krugman, Paul R. (1979): A Model of Innovation, Technology Transfer, and the World Distribution of Income, Journal of Political Economy 87(2), 253-266.

Krugman, Paul R., and Maurice Obstfeld (2006): International Economics, theory and policy, Addison Wesley, Reading, MA.

Lachenmaier, Stefan, and Ludger Wößmann (2006): Does innovation cause exports? Evidence from exogenous innovation impulses and obstacles using German micro data, Oxford Economic Papers 58, 317-350.

Lacroix, Robert, and Philippe Scheuer (1976): L'effort de R&D, l'innovation et le commerce international, Revue économique 27(6), 1008-29.

Leontief, Wassily (1953): Domestic Production and Foreign Trade: The American Capital Position Reexamined" Economics Internationale 7, 3-32.

Levitt, Theodore (1965): Exploit the product life cycle *Harvard Business Review* 43, 81-94.

Magnier, Antoine, and Joël Toujas-Bernate (1994): Technology and Trade: Empirical Evidence for the Major Five Industrialized Countries, Weltwirtschaftliches Archiv 130(3), 494-520.

Meyer-Krahmer, Frider (2004): Vorreiter-Märkte und Innovation, in: Steinmeier, F.W. and Machnig, M. (Ed.): Made in Deutschland 21', Hamburg, 95-110.

Pfirrmann, Oliver (1994): The geography of innovation in small and medium-sized firms in West Germany, Small Business Economics 6(1), 41-52.

Porter, Michael E. (1990): The competitive advantage of nations, New York.

Posner, Michael V. (1961): International Trade and Technical Change, Oxford Economic Papers 13 (3), 323-341.

Prais, S. and C. Winsten (1954): Trend Estimation and Serial Correlation, Cowles Commission Discussion Paper No. 383, Chicago, 1954.

Prize Committee of the Royal Swedish Academy of Sciences (2008): Trade and Geography – Economies of Scale, Differentiated Products and Transport Costs, Stockholm, http://nobelprize.org/nobel_prizes/economics/laureates/2008/ecoadv08.pdf

Schumpeter, Joseph (2004): The Theory of Economic Development, 10 reprint, Transaction Publishers, New Brunswick, NJ.

Soete, Luc L.G. (1981): A General Test of Technological Gap Trade Theory, Weltwirtschaftliches Archiv 117(4), 638-660.

Spatz, Julius, and Peter Nunnenkamp (2002): Globalisation of the Automobile Industry, Kiel Working Paper No. 1093, Kiel.

Taylor, Michael .J. (1986): The product-cycle model: a critique, Environment and Planning 18(6), 751-761.

Treubal, Morris (1975): Toward a Neotechnology Theory of Comparative Costs, The Quarterly Journal of Economics 89(3), 414-431.

UNCTAD (United Nations Conference on Trade and Development) (1999): Worlds Investment Report 1999: Foreign Direct Investment and the Challenge of Development, New York.

Valentine-Urbschat Michael and Wolfgang Bernhart (2009): Powertrain 2020 – Challenges and opportunities for OEMs and suppliers, proceedings of Electric Vehicle Symposium (EVS24), Stavanger, Norway, May 13-16, 2009.

Vernon, Raymond (1979): The Product Cycle Hypothesis in a New International Environment, Oxford Bulletin of Economics and Statistics 41 (4), 255-267.

Vernon, Raymond (1966): International Investment and International Trade in the Product Cycle, Quarterly Review of Economics 88, 190-207.

Vickery, Graham (1996): Globalisation in the Automobile Industry, in: OECD (Organisation of Economic Co-Operation and Development), Globalisation of Industry, Paris, 153-205.

Walz, Rainer (2006): Impact of strategies to increase RES in Europe on employment and competitiveness. Energy and Environment 17 (6), 951-975.

Table A1: Descriptive statistics of used variables (means for 1991 to 2008 per country)

Variable Definition	Variable Name	F	D	I	J	NL	SW	UK	US	OECD data table15
export of goods in the automotive sector [Billion $US\$_{current}$]	*auto_ export*	44.99	122.18	22.45	101.19	9.69	12.33	28.76	70.43	STAN Bilateral Trade ed2008
export of goods in all sectors [Billion $US\$_{current}$]	*economy_ export*	337	698	285	476	230	97	295	737	STAN Bilateral Trade ed2008
GDP per capita [$US\$_{current}$]	*gdp_pc*	24745	26372	24686	25943	28260	26934	25683	34367	Gross domestic product: GDP per capita
population [thousands]	*pop*	59203	81943	57453	126527	15840	8893	59011	279592	Population and yital statistic
R&D expenditures three to five years ago in the automotive sector [Millions $US\$_{current}$]	*rd*	2265	7392	943	7893	111	850	1208	13780	STAN R&D Expenditure in Industry ANBERD ed2009
unit labour cost [share]	*laborcosts*	0.68	0.69	0.69	0.61	0.69	0.68	0.70	0.67	Labour Income Share Ratios of total Economy

15 All data is provided by the OECD database on http://stats.oecd.org/index.aspx?r=281165

Authors' affiliations

Patrick Jochem

Institute for Industrial Production (IIP), Chair of Energy Economics,
Karlsruhe Institute of Technology (KIT),
Hertzstr. 16, 76187 Karlsruhe, Germany

Joachim Schleich

Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI),
Breslauer Strasse 48, 76139 Karlsruhe, Germany

Contact: Brigitte Kallfass

Fraunhofer Institute for Systems
and Innovation Research (Fraunhofer ISI)
Breslauer Strasse 48
76139 Karlsruhe
Germany
Phone: +49 / 721 / 6809-150
Fax: +49 / 721 / 6809-203
E-mail: brigitte.kallfass@isi.fraunhofer.de
www.isi.fraunhofer.de

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