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Exploring the drivers behind automotive exports in OECD countries: An empirical analysis

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Working Paper Sustainability and Innovation
No. S 3/2012

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Exploring the drivers behind automotive exports in OECD countries - an empirical analysis

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Abstract

The conceptual part of this paper ties the recently developed Lead Market concept to the international trade theory literature including neoclassical trade theory, new trade theory, neotechnological approaches and systems of innovation concepts. The empirical part explores the factors driving exports in the automotive sector in eight OECD countries between 1991 and 2008, explicitly accounting for possible Lead Market factors. 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 do not exhibit statistically significant effects on exports.

Keywords

Lead markets, international trade, export potential, 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) especially due to technology progress in telecommunication and information technologies. Innovations in globally-traded products tend to follow a common pattern: Products are invented in one country and usually first sold to domestic customers. Economies of scale help to lower production costs for successful innovations and open up additional markets abroad. Eventually, companies in other countries will follow the first movers and produce and export the same products or variations 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 an international context leads to a growing pressure on developed countries to continuously innovate. However, the product price is not the only factor driving export performance. Among others, quality and environmental impacts associated with production and consumption may also be important factors. As countries typically benefit from hosting the development and marketing of new products and technologies, the differences in their ability to do so have been the focus of academics and policymakers for some time (Fagerberg, 1996; Treubal, 1975; Krugman, 1979; Porter, 1990; Lundvall, 2007). 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”.

Over the last decade, the Lead Market concept has been developed and refined in the academic literature of business economics (Beise, 2001; 2004, Meyer-Krahmer, 2004; Beise and Rennings, 2005; Walz, 2006). The core of the lead market literature analyses identifies a wide range of factors affecting a country’s chance of becoming a lead market. Besides typical cost advantages, these factors also include demand conditions like domestic market size or the characteristics of domestic consumers, the general export orientation of countries and innovation friendliness (Meyer-Krahmer, 2004; Beise, 2004). The lead market concept foresees an active role for public policy in creating favourable frame-

work conditions which has been quickly recognised by policymakers at the national and international levels in their efforts to promote innovation (Blind et al., 2004). However, the lead market concept seems to be somewhat ad hoc, and no attempt has been made to link its main features to the economic trade literature in a comprehensive manner. Also, 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; Walz and Schleich, 2008; Rennings and Smidt 2010; Mathews et al., 2011).

In this paper, we first provide an overview of the economic theories of international trade and show how the lead market concept can be linked to these theories and related concepts. 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 also 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 also 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 variations 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 international economic trade theory and show how the lead market concept may be linked to this literature. Then we present the variables and data used in the econometric analysis. Estimation results appear in Section 4. The concluding section discusses the main findings and points to future research.

2 International trade theory and the lead market concept

2.1 Classical and neoclassical trade theory

Early economic approaches to explaining the patterns of trade across countries start with classical trade theory, which ranges from early theories about protectionism (Mercantilists) through the development of the principle of absolute cost advantage by Smith (1776) to the theory of comparative cost advantages and productivity by Ricardo (1817). While, for Smith, trade was only beneficial if 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 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 (i.e. resource) endowment, in technology (factor productivity) and in consumers' preferences across countries[1]. In this framework, the seminal contributions by Heckscher and Ohlin (Ohlin, 1924 and 1933, and Heckscher, 1919) explain production and trade patterns by countries' relative factor endowment. Most prominently, the factor productions theorem maintains that relatively capital-intensive countries export relatively capital-intensive goods and import relatively labour-intensive goods. In an extension of the Heckscher-Ohlin framework, Rybczynski (1955) considers absolute changes in factor endowment on production and their impact on trade patterns across sectors and countries. Subsequently, Samuelson's mathematical formulation of a two-country, two-sector, two-factor general equilibrium perfect competition model (Samuelson, 1948, 1949 and 1954) became the workhorse of theoretical and empirical research in explaining patterns of trade across countries and sectors and factor remuneration. This model, however, failed to explain actual empirical phenomena. Most notably, as pointed out by Leontief (1953), relatively capital-intensive (i.e. developed) countries also import some relatively capital-intensive goods and also export some relatively labour-intensive goods, which is at odds with the factor proportions theorem.

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

2.2 New International Economics

New International Economics builds on neoclassical trade theory, but includes concepts from the emerging field of industrial organisation and typically involves partial equilibrium models. 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. Above all, Krugman (1979, 1981) introduces economies of scale and monopolistic competition[2] and helps to explain the Leontief paradox and rapidly growing intra-industry trade. Together with Helpman and Krugman (1985), these papers initiated a comprehensive empirical research agenda on bilateral trade flows and also revived geographical economics (Brakman and Garretsen, 2009). Prior to the New International Economics literature, Linder (1961) had already explored the impact of demand-driven product differentiation on trade patterns.

In sum, the concepts presented so far identify 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, empirical research suggests that this set of factors is still not able to fully explain observed trade patterns and volumes (Helpman, 1999; Bowen et al., 1987; Trefler and Chun, 2000). Also, like classical and neoclassical theories, New International Economics is primarily a static concept and provides only limited insights into the development of trade patterns over time.

2.3 Dynamic trade concepts

The neo-technological approach highlights the role of technology in explaining the process of economic growth as well as differences across countries. One string, the Product Life Cycle theory (among others Vernon, 1966; Krugman, 1979; Gray, 1980; Dollar, 1986) explains trade patterns over time, thereby emphasizing the impact of the demand side. Originally developed within the business administration (marketing) literature to study national product markets (Levitt, 1965), the product life cycle theory has been taken up by the economics literature, in particular by evolutionary economics within the context of industrial life cycle (Dosi and Nelson, 1994). According to this theory, developed countries first export innovative products to other developed countries and then to less

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

developed countries. Countries which share more similarities in terms of their social, cultural and economic environments are more likely to adopt these innovative products (Grubel and Lloyd, 1975; Vernon, 1979). Over time, developing countries become better at 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). Therefore, developed countries need to innovate continuously if they want to sustain their customary levels of exports and incomes. Empirically, more innovative countries are expected to exhibit higher observed export levels.

Another string of the neo-technological approach, the Technology Gap theory (Posner, 1961) focuses on the supply side and explains differences in national income levels and growth rates by differences in the technology stock across countries, and by differences in the potential and ability of countries to adequately use resources to transform institutional, social and economic structures (Fagerberg 1987, p. 88).[3]

New Growth theory also focuses on the patterns of trade over time, accounts for dynamic comparative advantages (Romer, 1986; Grossman and Helpman, 1994) and combines concepts from the Heckscher-Ohlin theory, the product life cycle theory and spatial economics, which focuses on differences in policies and regional technology spillover effects. Unlike previous models, technological progress is no longer treated as exogenously given but is modelled as the outcome of economic activity. In these models, growth is driven by capital and knowledge accumulation with increasing returns to . However, like most of the models described above, the actions within or across individual firms are not explicitly modelled, nor are external context factors. In contrast, the literature on national (Lundvall, 1985, 1992, 2007; Freeman, 1987, 1995; Nelson, 1993) and sectoral systems of innovation (Malerba ,2002, 2005) also stresses the importance of intra-firm factors, interactive user-producer processes (Fagerberg, 1992), the role of institutions and regulation, technological capabilities and the home market characteristics for innovation and for competitiveness in international markets – in addition to demand and endowment factors.

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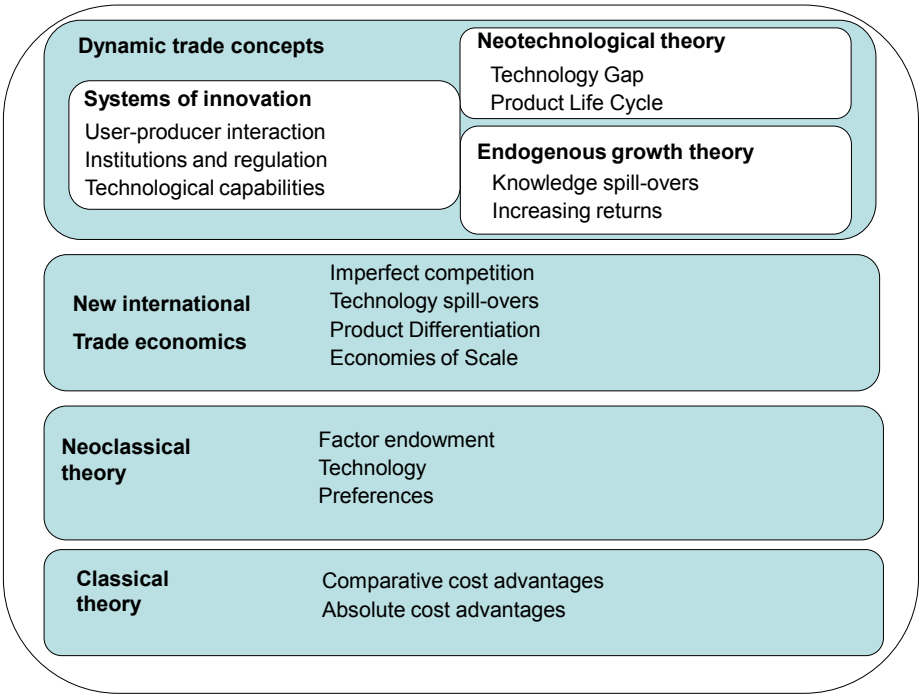
3 Empirically, technology gaps across countries can largely be explained by differences in expenditures for research and development (e.g. Fagerberg, 1987). For surveys on empirical findings, see also Wakelin (1997) and Archiburgi and Michie (1998).

Figure 1: Overview of international trade theories and their key drivers of the patterns of trade



In terms of policy, Porter (1990) stresses the role of governments for the international competitiveness of companies. Accordingly, regulation should enable national and international competition and stimulate innovations. The so-called "Porter Hypothesis" states that strict but flexible (environmental) regulations lead to innovations, improve the environmental performance and may also advance companies' competitiveness (Ambec et al., 2011). Hence, adequate environmental regulation may actually create lead markets for environmental products (e.g. Beise and Rennings, 2005; Walz, 2006).

2.4 Lead Market concept

Definition

The business economics-oriented concept of lead markets has been developed since the turn of the millennium (Beise, 2001, Meyer-Krahmer, 2004; Beise, 2004; Beise und Rennings, 2005). The lead market concept focuses on the export performance of innovative technologies and products. According to the definition adopted by the European Commission (2007:12) "*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.

Lead market factors of export performance

Conceptual and qualitative empirical research of lead markets have identified factors which are considered to positively affect a country's lead market potential. According to Meyer-Krahmer (2004), these factors include: (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. Largely based on Porter's (1990) four main groups of competitive advantages of a country, Beise and Cleff (2004) categorise five groups of determinants:(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 and the sensibility of the domestic market to foreign markets and global challenges or trends (e.g. environmentally-friendly products); (5) "market structure advantage", implying that strong domestic competition results in a higher probability that a company will manage to be successful abroad.

Link to existing trade theories

The lead market heuristic exhibits considerable overlaps with the different trade theories and concepts described in the previous sub-sections, in particular with the neo-technological theory and the systems of innovation approach. As in the technology gap theory, the ability of a country to become a lead market depends on its comparative technological capability and on favourable social and institutional conditions. Similar to the product life cycle theory, the lead market heuristic recognises different phases which are driven by varying demand conditions. Product life cycle theory presumes an upwards trend in demand during the early stages of a product's implementation. Demand for these products may then decline in the inventor region, but increase in other countries with comparable demand characteristics (Vernon, 1979). Translated into the development of an industry, the first phase of experimentation is marked by frequent entries and exits, many different technological alternatives and a small market volume. The second phase is characterised by market growth and consolidation of the suppliers (fewer new entrants, concentration of suppliers). The importance of the home market, of "transfer advantage" and of "market structure advantage" (cf. Cantwell, 2005; p. 560; Fagerberg, 1996) as well as of favourable institutional and social framework conditions for competitiveness on the international markets can be traced back to the systems of innovation literature. The systems of innovation literature also recognises that the functions of innovation systems vary by product cycle phases (Bergek and Jacobsson, 2003). While in the phase of experimentation, creation of new knowledge and guiding the search process are important functions, the formation of a mass market becomes the key prerequisite in the market growth phase. Notably, the lead market factors identified by Meyer-Krahmer (2004) and Beise and Cleff (2004) resemble the fourfold diamond of the competitive advantages of nations described by Porter (1990): (1) factor conditions, (2) demand conditions, (3) related and supporting industries as well as (4) firm strategy, structure and rivalry. These groups have subsequently been refined in the literature (e.g. Dunning 1997, Rugman et al., 1995) and empirically evaluated (e.g. Lindström, 2002). Like Porter (1990), the lead market concept also emphasises the evolutionary character of competitive advantage.

3 Methodology, variables and data

We consider the automotive sector an appropriate case to empirically analyse the impact of various factors on a country's 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, 2006). Further, although the automotive market is a late developer with respect to globalisation (UNCTAD, 1999:83), it has benefitted substantially from globalisation (Spatz and Nunnenkamp, 2002), with production sites in many developed countries and, more recently, also in emerging economies. Jacob et al. (2005) use the automotive sector as a case study to analyse the lead and lag market factors in the context of fuel-efficient passenger cars, catalytic converters, fuel cell vehicles, and emission reduction technologies for diesel vehicles. Likewise, Wietschel and Seydel (2007) analysed the conditions necessary for the European automotive sector to become a lead market for hydrogen and fuel cell technologies. In many countries, the automotive sector (including component suppliers) is a key sector in terms of employment, innovation and value added. Hence, factors driving success in automotive export markets are also of interest from a public policy perspective. For example, politicians' willingness to use tax money to "protect" car manufacturers in the US and Europe during the recent financial and economic crisis 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, potentially leading to a shift 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, markets and new production sites.

In order to empirically assess the contribution of the lead market concept to explaining countries' export performance, appropriate indicators need to be identified and sufficient data needs to be available for these indicators. In addition, even if sufficiently long time series data is available, many lead market indicators (such as per capita income or population size) do not vary much over time. Hence, the variation in variables for analyses based on time series data for a single country may not allow meaningful statistical analyses. Cross-country analyses, on the other hand, are likely to suffer from lack of observations (degrees of freedom), since a particular product or technology may not be produced in every country. This is especially true 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 also suffer from the so-called “omitted variable” bias. That is, if relevant variables are not included in the regression equation (e.g. due to a lack of data) and if these variables are correlated with the included explanatory variables, biased estimates of the parameters associated with these variables result. 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, or 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, we apply panel data analysis to econometrically explore the factors driving exports in the automotive sector.

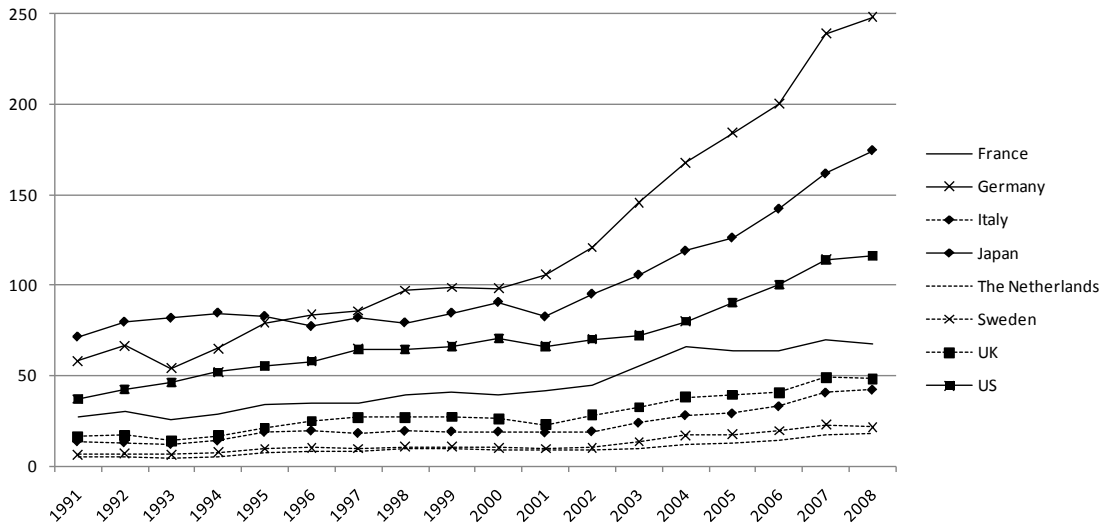
Data for our analyses stems from the OECD STAN Industry database. Our sector of interest is classified in the ISIC sector 34 “manufacture of motor vehicles, trailers and semitrailers” which also includes their suppliers.[4] National exports by the automotive sector serve as the dependent variable in the subsequent econometric analysis.[5] 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 the general export advantages of a country, stemming, among others, from spill-overs 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 sec-

4 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).

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

tor within the last three to five years (*rd*) are assumed to capture effects like rapid learning by suppliers, innovation friendliness or transfer advantages. Finally, country dummy variables are included to capture country-specific effects.

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 these 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 the export performance of the automotive sector. To avoid singularity of the regressor matrix, no country dummy was included for the US, which serves as the basis. Also, four year dummies are included to capture the 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, since stationary tests for panel data suggest that the dependent variable is trend-stationary, a time trend is included.[6]

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

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 country dummies and time trend)

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

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.[7]

4 Estimation results

We use STATA 11 to estimate equation (1) via the Feasible Generalized Least Square Estimator accounting for heteroskedasticity and for autocorrelation[8]. Estimation results appear in Table 2.[9]

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.

7 The only exception is the variable “share of labour income in value added”, which enters the equation without any transformation.

8 Autocorrelation is captured via the Prais-Winsten transformation. The Prais-Winsten estimator can be employed as the number of years is sufficiently high and larger than the number of countries.

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

Table 2: Regression results

Dependent variable: *auto_export*			
Variable	**Coefficient**	**Standard Error**	**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 (see Table 2). The parameter estimates associated with economy-wide exports and GDP per capita are 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 results in lower exports – we interpret this as equivalent to higher labour costs and assume a constant share of automation within the automotive sector for the considered OECD countries. In comparison, neither population nor expenditures for research and development turn out to be

statistically significant.[10] Also, while the trend variable is not (but almost) statistically significant at conventional levels, three of the four year dummies capturing economic downturns are all negative and statistically significant (at $p < 0.01$). Similarly, 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 reviewing the main theories of economic trade literature, we have shown how the emerging lead market concept can be embedded in these theories. Conceptually, the lead market concept relates strongly to the technology gap theory and the product life cycle theory and also to concepts more specific to the systems of innovation heuristic such as “transfer advantage” or “innovation friendliness”, but it also stresses the importance of factors derived from the marketing literature such as “lead users”. The classification of a lead market is quite similar to the classification developed in Porter (1990) to characterise the competitive advantages of nations. So far, empirical applications of the lead market heuristic consist of qualitative case studies.

The results of econometrically analysing the relevance of lead market and other factors in determining the export performance of the automotive sector in a panel of 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. In contrast to what might be expected of the lead market concept or the endogenous growth theory, however, the variable for sector-specific research and development expenditures was not found to have a statistically significant effect on export performance. This finding is in line with Fagerberg (1995), who does not find a significant relation between research and development intensities and trade performance for the automobile and many other industry sectors. Most other studies from the innovation literature, however, including Lacroix and Scheuer (1976), Magnier and Toujas-Bernate

10 When interpreting this finding, it should be kept in mind that the measuring methods for R&D in the STAN database differ across countries. 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 the UK. Furthermore, the country-specific measurement of R&D expenditures in multinational companies is not unambiguous.

(1994), or Fagerberg (1996), conclude that the trade performance of industry sectors is positively related to research and development expenditures or to patenting activity (Soete, 1981; Amable and Verspagen, 1995).

Hence, our findings provide some rationale for policy intervention which aims at increasing exports in the automotive sector. In particular, effective measures would have to address factors improving the general export performance of a country or lowering labour costs.

The relationship between government intervention and success in export markets also figures in current debates on the future development of electric vehicles. A shift towards electric vehicles means that crucial vehicle components would have to be altered. Most prominently, the technologically rather complex combustion engine with its sophisticated gearbox would be replaced by a relatively simple electric motor. A key technological challenge here is to develop a cost-efficient, space-saving battery capable of 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 for successful product introduction and 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, this is 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 research and development expenditures may not be an effective measure to increase exports.

While our findings should be interpreted carefully, they also point to avenues for future research. For example, our variable reflecting the impact of domestic demand factors on 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 could try to capture these preferences in empirical analyses. Likewise, research and development expenditures and their effect on exports are 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 on high-performance

batteries for electric vehicles. In addition, the future relevance of research and development for the automotive sector may shift from car manufacturers (combustion engine) to component manufacturers in the mechanical and electrical engineering sectors (electric motor), further strengthening the position of suppliers (Valentine-Urbschat and Bernhart, 2009). Hence, future empirical analyses may have to include automotive-specific research and development expenditures in these sectors at home and – in light of the continuing globalisation of companies – also abroad. Similarly, not all the (lead market) factors identified by the literature as affecting export performance could be included in the analysis due to a lack of data. This is particularly true for factors emerging from the systems of innovation literature. Thus, it is left to future research to find adequate proxies to capture supplier-user interactions or the institutional and regulatory framework and include these in multivariate analyses.

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 to other applications.

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7 Appendix

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 table[11]
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 vital statistic
R&D expenditures three to five years ago in the automotive sector [million US$ $_{current}$]	*rd*	2265	7392	943	7893	111	850	1208	13780	STAN R&D Expenditure in Industry ANBERD ed2009
unit labour cost [share]	*labourcosts*	0.68	0.69	0.69	0.61	0.69	0.68	0.70	0.67	Labour Income Share Ratios of total Economy

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

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Patrick Jochem is head of the research group “Transport and Energy” at the Institute for Industrial Production (IIP) at the Karlsruhe Institute of Technology (KIT), Germany. In 2009 he received a PhD in Economics (Dr. rer. pol.). Between 2006 and 2008 he held a scholarship from the German Federal Environmental Foundation (DBU). He worked as a research fellow at the Institute for Economic Policy Research (IWW) and Institute for Resource Efficiency and Energy Strategies (IREES). He studied economics at the universities of Bayreuth, Mannheim, and Heidelberg (Dipl.-Volksw.; 2005). His research interests are in the fields of transport and energy economics, modelling, econometrics, CO_2 emission trading, and sustainability.

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