Fragmentation, heterogeneity and intra-product trade within Europe

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Abstract

Fragmentation implies increasingly specialization of firms within the value chain of an industry or product. This means that firms become increasingly heterogeneous because each fragment of the value-chain requires different resources and capabilities, which results in different scale economies. The origin for this argument is found in Adam Smith's idea of the division of labour, the debate on increasing returns and the representative firm in the Economic Journal (from 1926 to 1930), and more recent discussions on firm heterogeneity in the econometric literature. Since fragmentation requires increasing intra-product trade, it has important implications for trade theory.

This paper will discuss the fragmentation issue in the context of this literature and test whether this process is deepening. The increasing heterogeneity of firms within an industry can be tested by considering selected characteristics of firms, such as scale economies, growth of firms, profit rate differentials, use of intangible assets, intermediate consumption, wage levels, import-intensity and export-intensity. We use employment data from the Amadeus database to create a panel of firms and use multilevel modeling to identify the trends in heterogeneity across European firms. Using the data, we consider that segments of the value chain may be similar across industries, or what the literature describes as vertical disintegration. If firms in different industries specialize in the similar segments of the value chain, they often become more similar to each than other firms in the same industry.

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1. Introduction

Fragmentation implies increasingly specialization of firms within the value chain of an industry or product. This means that firms become increasingly heterogeneous because each fragment of the value-chain requires different resources and capabilities, which results in different scale economies. Adam Smith (1776) knew that an ever more sophisticated division of labour implies an ever increasing fragmentation of knowledge. He also knew that this dynamism also generates heterogeneity and diversity of knowledge through the production of new goods and services. Ricardo (1828) and later Sraffa (1960) also saw the important role that this dynamism plays within the circular flow of production, and in the generation of a surplus that promotes consumption, growth and international trade.

This paper will discuss the fragmentation issue in the context of classical political economy and more recent contributions by Jones (2000), Armdt and Kierzkowski (2001), Melitz (2003), and Helpman, Meltz and Yeaple (2004) and test whether this process is deepening. The increasing heterogeneity of firms within an industry can be tested by considering selected characteristics of firms, such as scale economies, growth of firms, profit rate differentials, use of intangible assets, intermediate consumption, wage levels, import-intensity and export-intensity. We use employment data from the Amadeus database to create a panel of firms and use multilevel modeling to identify the trends in heterogeneity across European firms. Using the data, we consider that segments of the value chain may be similar across industries, or what the literature describes as vertical disintegration. If firms in different industries specialize in the similar segments of the value chain, they often become more similar to each than other firms in the same industry.

We organized the paper in the following way. In the next section we outline a theory of fragmentation from Adam Smith to Allyn Young and trade theory. The basic idea of fragmentation extends Smith's idea of the division of labour to international trade. In the global context, fragmentation may occur with a given firm, but it has become increasingly the case that individual tasks or groups of tasks be performed spatially apart, and/or separated by

ownership. The more global the fragmentation process becomes, the more important that international trade becomes. A second important problem is that emerges more promanetly in Allyn Young is that firms may become more heterogeneous as a consequence of the ever more sophisticated division of labour. The second section will weave this issue into the discussion on fragmentation. A third section will discuss some issues of heterogeneity as they are discussed in the trade literature and in particular, in Helpman, Meltz and Yeaple (2004). They argue that there is considerable heterogeneity within an industry, but attempt to measure this by examining the importance of heterogeneity across firms. We develop a simple multilevel model to identify the trends in heterogeneity across European firms. In the fourth section we present the results and in the concluding section we suggest a direction where take this analysis.

2. Fragmentation from Adam Smith to Allyn Young to trade theory

Adam Smith (1776) knew that an ever more sophisticated division of labour was the main source of productivity growth, but it also implied an increasing fragmentation of knowledge across the different tasks.[1] An increasing division of labour was seen by Smith to increase of dexterity of workers, save time lost in switching between different tasks, and lead to the invention of machines and organization that facilitate work. Trade theory becomes essential to the argument because the division of labour is limited by the size of the market. International trade increases the size of the potential market and provides a vent for any surplus product, but more importantly, it tends to create specialization across countries as task are subdivided into well-defined activities and products. One important implication of Smith's theory of productivity growth when combined with trade theory is that increasing fragmentation of knowledge can occur across countries and across firms with different ownership.[2]

[1] Though Smith did not regard the division of labour as a consequence of inequality, it may have appeared the first time in Plato's *Republic*, where it is the main source of inequality. William Petty knew that people with no extensive training could perform many of the tasks in the division of labour.

[2] Smith's idea of the division of labour should be placed in the context of the classical theory of production and the concept of capabilities. The basic idea that production is a circular flow (production of commodities by means of commodities) and that it involves physical real costs goes back to at least Adam Smith. David Ricardo (1828) and later Piero Sraffa (1960) also saw the important role that this dynamism plays within the circular flow of production, and in the generation of a surplus that promotes consumption, growth and international trade.

Smith's theory of international trade was based on the concept of the division of labor.[3] For Smith productivity growth and market growth generates international trade in Smith since knowledge often fragmented across national boundaries, as well as across different firms and organizations. International trade widens the market and gives vent to the resources that, in the absence of trade, would remain unemployed or underemployed. International trade, by overcoming the narrowness of the domestic market, ensures that the division of labor is carried more fully and productivity growth is higher. A country produces products for which it is best suited (i.e., for which its absolute costs are lower) in terms of natural or acquired advantages and exchanges its surplus produce with the produce of other countries for which there is a demand in the home market. Free trade not only ensures gains to the consumers who get a product at a lower price but it also ensures more productive deployment of domestic capital.

Causality between productivity growth and the division of labour ran both directions in Smith. Smith was careful to bring out its two-way link with the division of labor when discussion the accumulation of capital. When he stated that the use of machinery facilitated and abridged labor, he pointed out that the accumulation of stock is, in the nature of things, previous to the division of labor. As the division of labour became more sophisticated, the incentive to innovation become greater. Further, subdivision of tasks requires more capital to keep busy all the different kinds of workmen. The more the productive hands employed, as a result of the higher division of labor, the more the capital required for wage advances as well as to equip them with proper tools and equipments. Thus capital accumulation (including machinery) is both a cause and effect of the division of labor.

In a modern knowledge-based economy, the division of labour drives the division of knowledge, the knowledge based economy refers to a context in which the division of knowledge drives the division of work. It is easy to see parallels between Smith's idea of the division of labour and modern growth theory as these activities can be equated with learning by doing, set-up costs, human capital and endogenous technical progress (Lavezzi, 2003). Various modes of learning lead to specialized forms of knowledge.

More on the fragmentation of knowledge. Loasby (1988) pointed out that the division of labour encourages the development of differentiated knowledge, and therefore of distinctive

[3] As Myint (1977, 231) pointed out, "Smith's theory of foreign trade is so closely interwoven with his theory of domestic economic development that the two have to be considered together".

capabilities, which are 'knowledge how' rather than 'knowledge that'. (Skills and activities were central to productivity growth in Smith's argument. The specialization and concentration of the workers on their single subtasks often leads to greater skill and greater productivity on their particular subtasks than would be achieved by the same number of workers each carrying out the original broad task.)[4]

Allyn Young (1928) developed the idea that the division of labour is a form of industrial fragmentation more fully than Adam Smith.[5] Writing in the later half of the eighteenth century when industrial capitalism was in its infancy, Smith could not fully visualize that industrial stratification implies a division of labor among firms and industries. The idea of industrial fragmentation in Young was linked to the 1920s debate on the representative firm. For Young, fragmentation was a response to changes in the market external to the firm. As a consequence industries would gradually lose their identity in response to changes in the external field. Neither the concept of a firm or industry losing its identity nor that of external economies is present in Smith.[6] But Smith developed the idea that different specialized arts and crafts have to join hands even for the production of the most ordinary goods and services.[7] (More on Young)

From Young to Kaldor – from a micro view of fragmentation to a macro view. Young couched his explanation of growth in terms of macro increasing returns, the transmission of which required more competition rather than less. He extended Smith's conception of the division of labor to include industry level specialization; it was the process of industrial fragmentation rather than integration, which lay at the heart of increasing returns. Growth was essentially a disequilibrium process the study of which could not be accomplished with ceteris paribus tools. Economies of scale, in his view, were only incidental to the broader phenomenon of increasing returns. In a Kaldorian context heterogeneity generates trade and trade generates heterogeneity.

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[4] P. Llerena argues that the "division of knowledge " (as expressed by the delineation of the domain of core competences) "precedes" the division of labour the firm functions as a knowledge processor giving full priority to the creation of resources.

[5] He also knew that this dynamism also generates heterogeneity and diversity of knowledge through the production of new goods and services.

[6] Young suggests that this trend may lead to new forms of industrial organization.

[7] Smith's discussion of growth was much broader than that of Young. For he not only discussed growth mechanics (which Young developed more fully later) but also the role of institutions, systems, and conditions for a competitive exchange economy to work, without which the potential of the division of labour to bear productivity gains becomes restricted.

3. Where is the heterogeneity?

There is a burgeoning literature in trade theory that drops the assumption of the representative firm and instead explores the behavior of heterogeneous firms within the context of an open economy model (see Wagner, 2005). This discussion started with the paper by Bernard and Jensen (1995) that used a large panel of U.S. plants to demonstrate that exporters and non-exporters differ within industries. An influential paper by Helpman, Melitz and Yeaple (2004) that used a multicountry, multisector general equilibrium model shows that the choice between exports and FDI depends on organizational structures and the degree of heterogeneity within the industry. The model predicts that the least productive firms will service only the domestic market, relatively more productive firms export, and the most productive firms engage in FDI. To determine the extent of intra-industry heterogeneity, the authors develop a regression-based measure of dispersion based on a Pareto distribution from the 1997 U.S. Census of Manufacturing and a sample of 260,000 European firms reported in the Amadeus Database.[8]

Our main contention is that heterogeneity is greater within an industry then across industries and that this kind of heterogeneity would have an implications for the choices that firms will make if their objective is to minimize physical real costs. As in the paper by Helpman, Melitz and Yeaple (2004), we use the full Amadeus database available from Bureau van Dijck Electronic Publishing. The database contains information on the consolidated balance sheets of over 9 million firms, but we needed to restrict our sample to the level of employment for all firms with at least 10 people employed at any time from 1996 to 2004 because of size. The total dataset we used in the estimation contained over 5 million observations for employment from 29 countries from 1996 to 2004.[9]

We compute the importance of intra-industry heterogeneity through the use of multilevel modeling. Multilevel modeling, which is sometimes called, mixed models or mixed-effects models, are tailored for this purpose (Luke 2004). We distinguish between different characteristics of firms, which are firm- and industry- specific. Firms can be classified into industries, but various characteristics of both individual firms and industries

[8] In the paper they take the standard deviation of log(sales) by industry $(1/(k-\sigma+1))$.

[9] These countries included Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.

may be relevant at the same time. Initially, we consider certain technological characteristics (opportunities) to be shared by all firms within an industry (along the value chain). Production of chemicals differs from manufacture of a microchip, but it does not mean that firms in the microchip industry are alike in term of scale economies, business strategy, etc. We want to determine whether the observed differences among firms can be attributed to heterogeneity between industries or within them.

To capture these differences in heterogeneity, we estimate a basic two-level multilevel model. The aim of a two-level multilevel model is to estimate values of some dependent variable based on predictors at more than one level. For example, we may want to examine to which extent firm's scale economies is specific to the firm and to which extended it is influenced by the industry. In this case the firm represents level-1 and the industry level-2 of the analysis. The following two-level model can delineate the multilevel nature of the problem:

Level 1: $Y_{ij} = \beta_{0j} + r_{ij}$

Level 2: $\beta_{0j} = \gamma_{00} + u_{0j}$

where Y is the dependent variable, *i* is the firm, *j* is the industry, β_{0j} is the level-1 intercept in level-2 unit *j*; γ_{00} is the mean value of the level-1 dependent variable, r_{ij} is the unmodeled variability (error) for unit *i* and u_{0j} is the unmodeled variability (error) for unit *j*.

This system of equations indicates that a different level-1 model is estimated for each of the *j* level-2 units. Each industry in our study may have a different average of the dependent variables (β_{0j}). In other words, we are allowing the intercept β_{0j} to vary across industries. A critical aspect of the two-level model is that the level-2 equation implies that the level-1 intercept is a function of level-2 variability, so that we can treat the intercepts as outcomes of the industry level. By substituting the level-2 equation into the level-1 equation we arrive to a reduced basic mixed-effects model:

Reduced: $Y_{ij} = \gamma_{00} + u_{0j} + r_{ij}$,

which is composed of a single fixed effect γ_{00} and two random effects r_{ij} at level-1 and u_{0j} at level-2. In our analysis, r_{ij} is variability accounted to the firm-level and u_{0j} is variability of the same dependent variable between industries. The former is the variability between firms

within an industry, which represent intra-industry heterogeneity, while the latter is the variability between industries, which refers to inter-industry heterogeneity.

Multilevel models become more complex if level-1 or level-2 predictors are introduced. For our purpose; however, it is enough to estimate the simplest possible two-level model with no predictors outlined above. The only purpose of this so-called unconstrained or null-model, is to disentangle how much of the variance of the dependent variable can be attributed to level-1 as compared to level-2 of the model, i.e. to the firm as compared to the industry level.[10] Since the multilevel model splits the random effect between the different levels, we can calculate the intraclass correlation coefficient (ICC), which is defined as follows:

$$ICC = \frac{\sigma_{u0}^2}{\left(\sigma_{u0}^2 + \sigma_r^2\right)} = \frac{u_{0j}}{\left(u_{0j} + r_{ij}\right)}$$

The ICC measures the proportion of variance in the dependent variable that is accounted for by the level-2 units. In our analysis, the ICC refers to percentage of variance in the log of the number of employees that is explained by the industry.

Table 1 shows the intra-class correlation coefficient (ICC) for Europe, 1996 to 2004.[11] The figures in the table show the percentage share of heterogeneity that can be explained by inter-industry variability. For example, if the ICC equals to 0.25 it means that industry account for 25 per cent of the variability of number of employees (in logs) among firms. The information contained in the table does not appear in any previous study, and its real uniqueness is in showing the trends over time. Consequently, we can look at the tables in terms of levels, trends and growth rates.

When we examine the table in terms of levels, it is best to use 2003 as a benchmark because the sample is unbalanced and the Amadeus database is not complete across time. Data from 2004 does not appear complete in the dabatase as of the end of 2005. The table shows that intra-industry heterogeneity predominates. Very little of the heterogeneity is inter-industry. There is also evidence that the share of intra-industry heterogeneity is increasing.

[10] It can be shown, that the null-model is equivalent to one-way random-effects ANOVA model (Luke 2004), where we assume that the group means are randomly varying. If we would add predictors only to the level-1 equation, the model becomes a random effects ANOVA.

[11] We estimated the multilevel model using HLM 6.0 statistical package. One-way random-effects (nested) ANOVA can be estimated in Stata 9.2, but with relatively severe restriction on size of the sample given in-build limits of the program on matsize (up to 11,000).

The UK is a good example of this, but the trend is also strong in some of the former centrally planned economies. These results could be related to changing number of observations or the fact that we use an unbalanced sample. But there is not a big drop in changes when the number of observations is taken into account.

If we compare the table with figure one, it becomes apparent that the level of development matters in whether the heterogeneity is intra-industry or inter-industry. In the table, Bulgaria and Romania has the highest heterogeneity explained by differences across industries. By contrast, figure two shows that exports of goods and services are not related to the ICC coefficient. This can be due to a variety of reasons already discussed in the literature. Finally, there appears to be some connection between real GDP growth and the percentage point change in the ICC coefficient. This may indicate that the division of labour is becoming more sophisticated but it can also indicate that the definition of an industry, as described in the ISIC and NACE accounting systems, is becoming more fuzzy as Allyn Young predicted.

4. Concluding Remarks (In presentation)

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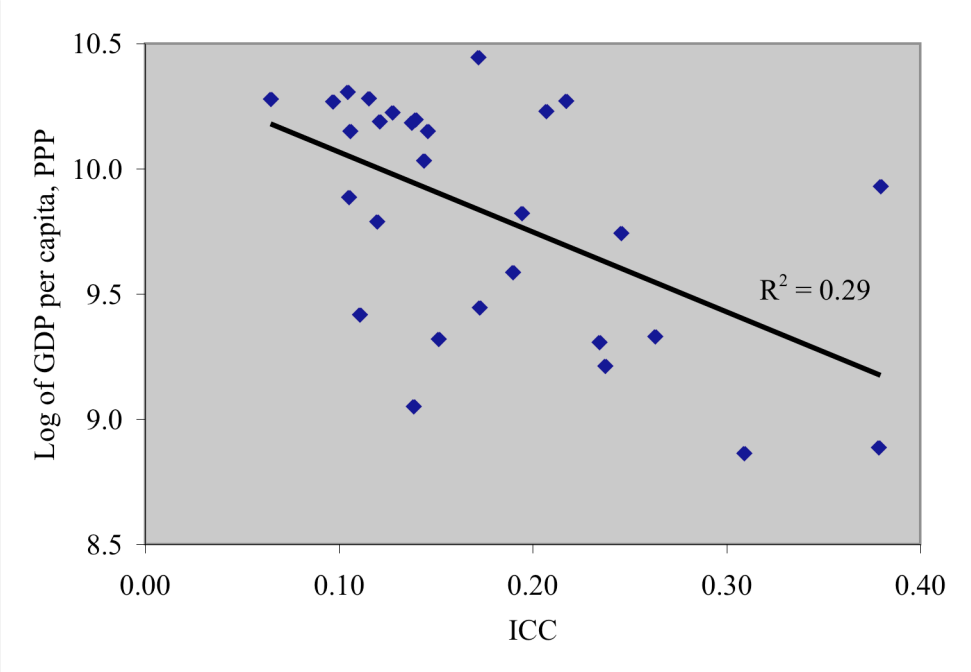
Tables and Figures

Table 1: The intra-class correlation coefficient (ICC) for Europe, 1996 to 2004.

	ICC coefficient								
Country	ICC96	ICC97	ICC98	ICC99	ICC00	ICC01	ICC02	ICC03	ICC04
Austria				0.16	0.16	0.13	0.14	0.12	0.12
Belgium	0.22	0.24	0.23	0.19	0.20	0.20	0.21	0.21	0.22
Bulgaria				0.34	0.37	0.36	0.32	0.31	0.26
Croatia			0.23	0.25	0.26	0.22	0.25	0.23	0.23
Cyprus				0.19	0.20	0.29	0.28	0.38	0.33
Czech Rep.	0.26	0.27	0.27	0.26	0.24	0.23	0.25	0.25	0.30
Denmark					0.09	0.10	0.10	0.10	0.10
Estonia		0.11	0.13	0.25	0.24	0.18	0.14	0.11	0.15
Finland	0.09	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.15
France	0.15	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.14
Germany				0.14	0.13	0.12	0.14	0.15	0.10
Greece	0.14	0.11	0.08	0.09	0.10	0.08	0.11	0.11	0.12
Hungary							0.19		
Ireland			0.08	0.07	0.06	0.06	0.06	0.06	0.05
Italy	0.13	0.09	0.11	0.12	0.11	0.12	0.12	0.11	0.12
Latvia			0.24	0.24	0.24	0.24	0.19	0.24	0.27
Lithuania					0.29	0.29	0.17	0.15	0.16
Netherlands	0.25	0.18	0.12	0.12	0.12	0.11	0.12	0.22	0.24
Norway	0.20	0.21	0.19	0.18	0.18	0.18	0.17	0.17	0.18
Poland	0.29	0.31	0.29	0.13	0.27	0.28	0.27	0.26	0.30
Portugal							0.11	0.12	
Romania	0.33	0.35	0.33	0.31	0.31	0.29	0.31	0.38	0.28
Russia			0.37	0.29	0.30	0.26	0.20	0.14	0.15
Slovakia								0.17	0.19
Slovenia	0.18	0.16			0.16	0.16	0.27	0.19	0.16
Spain	0.16	0.20	0.16	0.19	0.18	0.16	0.14	0.14	
Sweden		0.14	0.13	0.13	0.13	0.11	0.11	0.12	0.11
Switzerland	0.16	0.12	0.15	0.15	0.14	0.12	0.11	0.10	0.11
United Kingdom	0.17	0.19	0.18	0.16	0.15	0.13	0.13	0.13	0.13

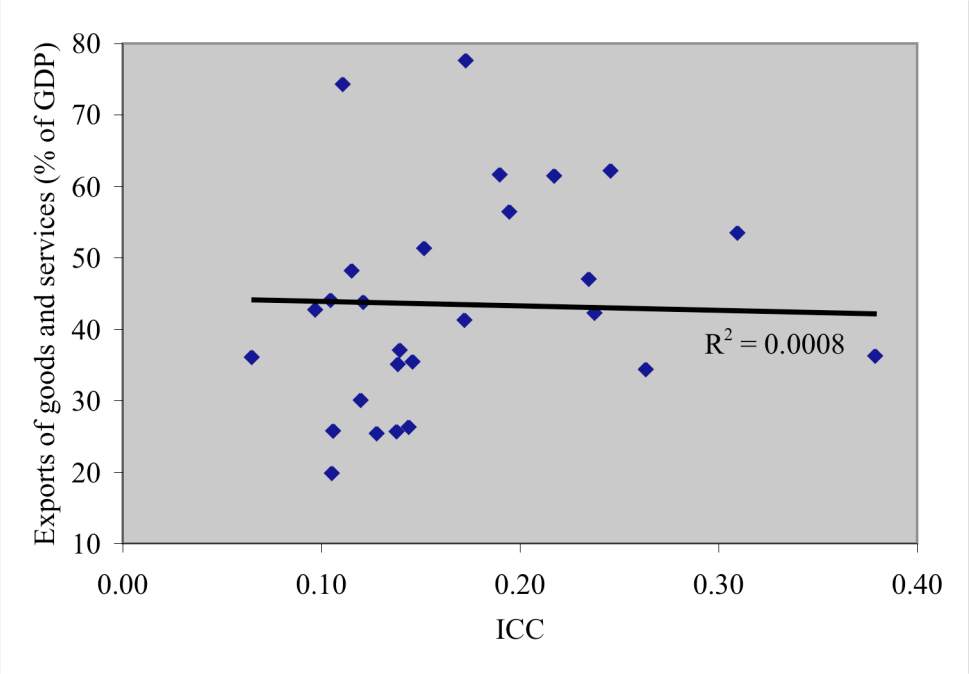
Source: Author's own calculation based on available data for firms with 10 employees or more from 2002 to 2004 in the Amadeus database.

Figure 1: The relationship between per capita GDP and the ICC coefficient, 2003



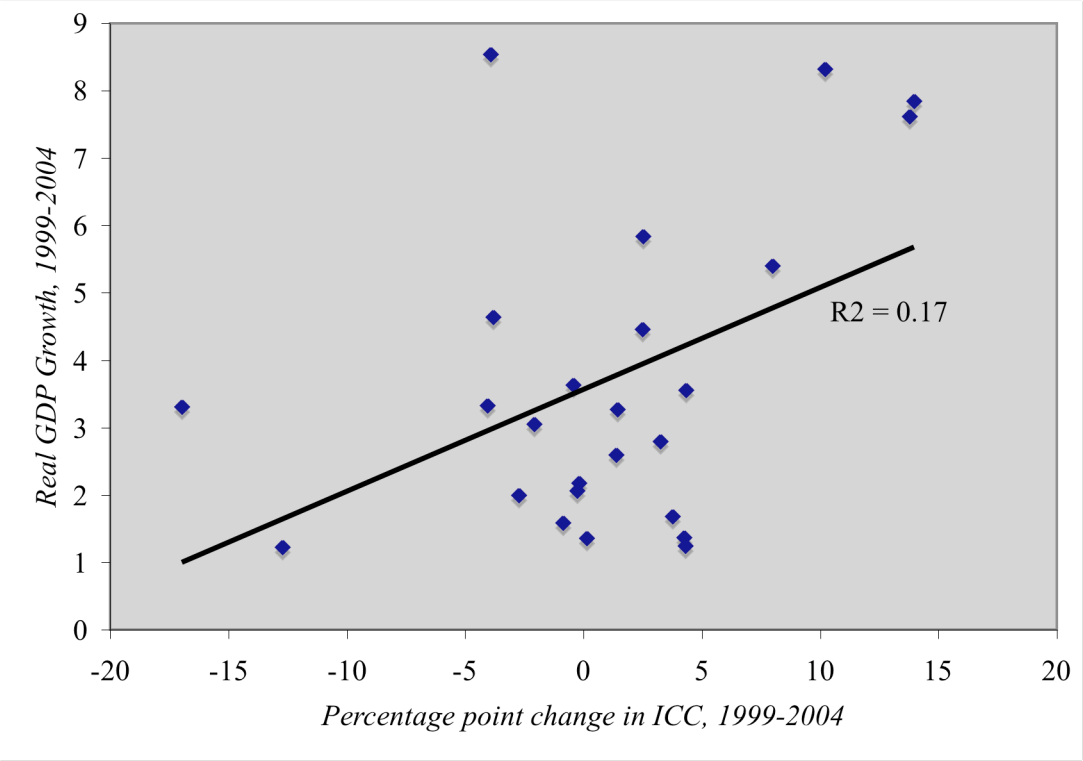
Source: Author's own calculation based on firms with 10 employees in the Amadeus database.

Figure 2: The relationship between Exports and the ICC coefficient



Source: Author's own calculation based on firms with 10 employees in the Amadeus database.

Figure 3: The relationship between real GDP growth and the percentage point change in the ICC coefficient, 1999-2004.



Source: Author's own calculation based on firms with 10 employees in the Amadeus database.