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Determinants of Export Specialization in ICT Products:

A Cross-Country Analysis

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Determinants of Export Specialization in ICT Products: A Cross-Country Analysis

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Abstract
In this paper the determinants of ICT export specialization are investigated with a panel-econometric analysis, which includes 28 countries. ICT exports are broken down into three broad ICT product groups (electronic data processing machines, integrated circuits and electronic components, and telecommunications equipment), and the determinants are examined for each of the above product categories. Our results indicate that technology factors, such as Research & Development expenditure and human capital constitute significant determinants. However, other deterministic factors, related to more recent trade theories, seem to be relatively more important.

JEL classification: F02, F10, F14

Keywords: Export specialization, Information and Communications Technology (ICT), ICT exports, Panel data analysis

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1. Introduction

Due to the deepening globalization process and the integration of some emerging economies into the world economy, the volume and patterns of high-tech electronics trade have changed substantially. In recent years, especially Information and Communications Technology (ICT) goods exports have increased significantly. More specifically, world exports in ICT products grew by 57% between 2000 and 2007 (for telecommunications equipment 95%) and amounted to 1,514 billion US dollars in 2007, representing about 20% of total world exports.[1] In terms of demand and value added, ICT goods are considered as one of the most dynamic products worldwide (UNCTAD, 2007). Moreover, there is evidence that suggests that countries with strong export specialization and performance in ICT-related products exhibit higher productivity and economic growth rates (Hausmann *et al.*, 2007; Rodrik, 2006; Farberger, 2000; Greenaway *et al.*, 1999).

Given these facts, developed and more recently developing countries pursue policies and devote national resources in order to promote industrial technological specialization and export high-tech products to the global market. However, even an increased export specialization in high-tech products does not necessarily indicate an enhanced technological production base and capability. This is because specialization can occur in low value-added and less technology-intensive activities in the value chain of the ICT product through the international production fragmentation process and outsourcing (Andersson and Ejermo, 2008; Srholec, 2007; Yi, 2003; Hummels *et al.*, 2001). China is one good example of this kind of export specialization in ICT products (Gaulier *et al.*, 2007; Amighini, 2005; Lemoine and Unal-Kesenci, 2004; Lemoine and Unal-Kesenci, 2002).

On the other hand, there is evidence suggesting that international technological spillovers may arise to a country's manufacturing industry from ICT goods imports and industrial linkages with technologically advanced economies (Lopez-Pueyo et al., 2009). More specifically, it is believed that countries benefit even from this vertical type of export specialization in ICT goods due to the rising involvement in high-tech related products of domestic firms, which in the long-run promotes technological advancement of the local manufacturing base (Liu, 2008; Todo and Miyamoto, 2006; Lemoine and Unal-Kesenci, 2004). Particularly in China, the technological advancement that has been achieved in the

[1] World Trade Organization international trade database.

ICT sector (Fan, 2008) seems to have been facilitated to a substantial degree by the country's extensive participation in the global production fragmentation (Gaulier *et al.*, 2007).

In any case, for many governments the local production and the exporting of high-tech consumer goods (such as ICT) has become one of the most important policy priorities. Knowledge of the country-specific factors determining the ICT export specialization within the world economy may provide relevant information and policy implications to policy makers. Therefore, the paper's objective is to empirically analyze the country-level determinants of export specialization in ICT goods.

The paper is organized as follows. In Section 2, stylized facts and trends in world ICT exports are briefly presented. In Section 3, the theoretical background and hypotheses of the determinants of ICT export specialization are discussed. Additionally, the explanatory variables that are included in the empirical analysis are presented. In Section 4, the econometric methodology is outlined. In Section 5, the empirical results are reported and discussed. Finally, Section 6 summarizes the main findings and concludes.

2. Global ICT Exports

As it is evident from Figure 1, overall world ICT exports have increased steadily since 2001 and onwards. A similar temporal development is evident for each of the three main ICT product groups. World exports in electronic data processing machines (EDP) increased from US$371 billion to US$540 billion, whilst those in integrated circuits and electronic components (ICEC) rose from US$307 to US$413 billion. World exports in telecommunications equipment have clearly witnessed the strongest growth, rising from US$288 to US$560 billion between 2000 and 2007.

This export growth has been so significant that telecommunications equipment has become the ICT product group with the highest share in total ICT world exports. More specifically, from 29.8% in 2000 the share increased to 37% in 2007, making telecommunications exports the most significant in total ICT world exports (Figure 2). The second most important ICT product group in terms of total global ICT exports is electronic data processing machines with a share of 35.7% in 2007. Evidently, the relative importance of integrated circuits and electronic components has fallen considerably between 2000 and 2007. This ICT product group represents only 27.3% of ICT exports in the world.

As regards the development in the relative importance of ICT exports in total manufacturing exports, it can be seen from Figure 3 that there has been a decline in this respect between 2000 and 2007. In particular, total ICT exports in 2000 accounted for 36.8% of total manufacturing exports in the world, whereas in 2007 this share shrunk to 31.4%. However, global telecommunications exports gained in relative importance during this period. The share of telecommunications products in total world manufacturing exports increased from 11% to 11.8%. The fall of ICT products relative to total manufacturing exports is attributable to the significant decline in the export share of ICEC products and EDP machinery. This, in turn, is a result of the impressive export growth that has been achieved in some non-ICT manufacturing products relatively to the export growth of those ICT product groups. ICT exports, however, still account for a large part (almost one-third) of total manufacturing exports in the world.

3. Deterministic factors of ICT export specialization

3.1 Theoretical Background and Hypotheses

The standard theoretical frameworks for analyzing and explaining cross-country trade specialization patterns are the Heckscher-Ohlin (H-O) and Ricardian trade models which together constitute the comparative advantage trade theory. In the ICT case, R&D (knowledge capital) and human capital (skilled labor) constitute the comparative advantage determinants.

Hence, in this ICT reformulated comparative advantage framework, the relatively R&D and human capital abundant countries will produce and export the good using these factors intensively (or in a dynamic setting an increase in those relative factor endowments results in an increase in ICT exports over time). Also, from the Ricardian view, an increased ICT-related technology input will result in increased technology-production capabilities and improved productivity, resulting in enhanced comparative advantage, and thus increased export specialization. Thus, according to the comparative advantage setting, technology-related inputs are expected to have a positive influence on ICT export specialization.

In the more recent and alternative theoretical framework of the new economic geography (NEG), originating from the new trade theory, on the other hand, trade and specialization patterns are not determined by comparative advantage. Instead, this framework draws attention to increasing returns to scale, transport cost, agglomeration economies and domestic market size for the determination of location and specialization patterns. In the

presence of economies of scale and transport costs, the production of a manufacturing good is located in the location with the larger market (of that good), which becomes a net-exporter of that good.

In our context, if ICT production is characterized by increasing returns, then, assuming positive international transport costs and market size differences, ICT firms will tend to locate in countries with a large ICT market. Hence, those countries will tend to specialize in and export ICT products (see, for instance, Grossman and Helpman, 1991). Furthermore, because of the existence of agglomeration economies within the industrial and high-tech sectors, countries, which exhibit large agglomeration economies due to a large industrial sector, will tend to attract more firms from other countries, resulting in greater export specialization.

The new economic geography stresses also the importance of a country's degree of international market access. Specifically, for our investigation, assuming that market access is also a relevant factor in the ICT case, the implication is that countries with good market access internationally will tend to exhibit higher export specialization in ICT products than countries with little or no such access.

3.2 Explanatory Variables

In our econometric analysis of the determinants of ICT export specialization, variables are included which proxy for the deterministic factors of the theoretical frameworks discussed above. Thus, though our analysis does not constitute a formal test of various competing trade theories, it sheds light on the relevance and relative importance of those frameworks in the ICT case. In addition, other determinants are included and tested. More specifically, the following explanatory variables are investigated:

- Comparative Advantage factors
    - R&D
    - Human Capital
    - Cost Competitiveness
- NEG factors
    - ICT Market Size (Home-market effect)
    - Agglomeration Economies
    - International Market Access
- General factors

- ICT-related public infrastructure
- Multinational firm activity

As already discussed, from the comparative advantage view R&D (*RD*) as well as human capital stock (*HC*) are expected to be positive determinants of ICT export specialization (*XS*). The R&D production input variable is proxied by the country's R&D expenditure as a percentage of GDP, whilst human capital stock is proxied by the country's number of researchers engaged in R&D-related research. Additionally, general domestic production cost conditions also determine comparative advantage through cost competitiveness (*CC*). This variable is proxied by the real effective exchange rate is expected to exert a negative effect on export specialization.

For the NEG's home-market effect in the ICT context, we include a country's ICT market size (*ICT*) as a positive determinant of ICT export specialization, which is proxied by a country's total ICT expenditure. In other studies the GDP is used, but here the market size must specifically reflect the domestic market size of ICT products. Agglomeration economies (*AE*), which are proxied by a country's manufacturing size (value added), contribute to the attraction of ICT firms in one country, and thus are also considered as a positive deterministic factor of a country's export specialization in ICT products. International market access (*IMA*) is also considered to exert a positive effect on a country's degree of ICT export specialization. This explanatory variable is proxied by a country's international openness index (trade-GDP ratio).

Regarding our two general deterministic factors, ICT-related public infrastructure (*INF*), proxied by the number of telephone mainlines per people, and the importance of multinational firm activity within a country (*MF*), proxied by the inward FDI stock to GDP ratio, are both expected to be positively associated with a country's ICT export specialization. In the first case, infrastructure may facilitate the local production and/or intra-country distribution of ICT goods and thus contribute, as a general supply-capacity factor, to export specialization in those goods. In the second case, foreign affiliates of multinational firms within a country may be engaged relatively more in ICT production, and/or create technological spillovers to domestic firms, leading to relatively more ICT-related production and specialization.

4. Econometric Methodology

According to the above outlined hypotheses, the model to be tested is summarized as follows:

$$XS_{it} = f\left(RD_{it}, HC_{it}, CC_{it}, ICT_{it}, AE_{it}, IMA_{it}, INF_{it}, MF_{it}\right) \tag{1}$$

with

$$\frac{\partial f}{\partial RD} > 0,\ \frac{\partial f}{\partial HC} > 0,\ \frac{\partial f}{\partial CC} < 0,\ \frac{\partial f}{\partial ICT} > 0,\ \frac{\partial f}{\partial AE} > 0,\ \frac{\partial f}{\partial IMA} > 0,\ \frac{\partial f}{\partial INF} > 0,\ \frac{\partial f}{\partial MF} > 0$$

The dependent variable (*XS*) is the Balassa index (of relative export specialization) in each of the three ICT product groups, defined by the following equation:

$$B_{ij} = \left(\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}\right) \cdot \left[\left(\frac{\sum_{j=1}^{m} X_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} X_{ij}}\right)\right]^{-1} \tag{2}$$

where X denotes exports and subscripts i, j, n, and m denote sectors, countries, total number of sectors, and total number of countries in the country group (the world economy), respectively. The explanatory variables are the proxies discussed earlier. A detailed description of the variables and data sources is provided in the appendix.

Our empirical analysis of the country-level determinants of export specialization in ICT products is based on a panel data econometric framework. In particular, for the model's general function shown in equation (1), a linear panel regression equation is chosen for estimation, which takes the following form:

$$\begin{aligned} XS_{it} = {} & \beta_0 + \beta_1 RD_{it} + \beta_2 HC_{it} + \beta_3 CC_{it} + \beta_4 ICT_{it} \\ & + \beta_5 AE_{it} + \beta_6 IMA_{it} + \beta_7 INF_{it} + \beta_8 MF_{it} + \mu_i + \varepsilon_{it} \end{aligned} \tag{3}$$

where i stands for countries ($i=1,2,...,28$)[2], t denotes years (yearly observations: $t=2000,...,2005$), μ_i represents the unobserved country-specific effects, and ε_{it} is the stochastic error term. Since we analyze the determinants of export specialization in each of our three ICT product groups, three regression models are estimated.

The inclusion of the country-specific effects is particularly important in order to control for omitted variables bias as well as to account for unobserved individual heterogeneity. Hausman tests are conducted in order to reveal the appropriate panel specification (fixed or random effects). The null hypothesis of the Hausman test that the individual specific effects are uncorrelated with the regressors is clearly rejected in all of the tree models ($\chi^2(8)$=30.2 [p=0.000]; 21.1 [0.001]; and 27.3 [0.000]). Thus, one-way fixed-effects panel estimation is used for our models.

As heteroscedasticity is detected in all models, it is corrected by estimating the models with White-robust standard errors. Additionally, in order to control for the presence of serial correlation a first-order autoregressive term, AR(1), is included. On the other hand, collinearity diagnostics indicate there is no problem with multicollinearity, and thus we retain all explanatory variables in the model for estimation.

5. Empirical Results

Our econometric results on the determinants of ICT export specialization in each of our three ICT product groups are reported in Table 1. In addition to the regular regression coefficients, standardized (beta) coefficients as well as elasticities are also shown. Turning first to the model for electronic data processing machines, it is evident that all regressors show the expected sign, with the exception of multinational firm activity. However, our hypothesis of a positive impact of MF must not be generally true, since inward FDI within a country may be concentrated in activities that are not related to electronic data processing machines. In fact, the statistically significant negative coefficient indicates that countries with a high FDI-GDP ratio exhibit lower export specialization. This in turn implies that a large part of the inward FDI stock of those countries might be concentrated in the non-ICT sectors.

Statistical significance at various levels is found in all explanatory variables. R&D expenditure, international market access, infrastructure, and agglomeration economies are highly statistically significant. On the other hand, the coefficient of human capital is

[2] Taiwan is dropped out from the analysis due to lack of data.

only significant at the 10% level. Both fixed-effects tests (F and χ^2) show that the unobserved country-specific fixed effects are highly significant, indicating that besides the regressors included in the model unobserved factors play a role in the context of the model.

In order to examine the relative importance of the determinants of export specialization in electronic data processing machines and in the other two ICT product groups, we have also estimated standardized regression coefficients. The standardized coefficients, also referred to as beta coefficients, indicate the magnitude of the impact of an independent variable on the dependent variable, and thus show the relative importance of various explanatory variables of the model. More specifically, the beta coefficients, which are unit-free, show how many standard deviations the dependent variable moves on average when the independent variable moves one standard deviation.

According to our beta analysis, the most important determinant in the EDP model is found to be international market access. The beta coefficient indicates that an increase of one standard deviation in this variable results in an increase of about 0.44 standard deviations in the export specialization in electronic data processing machines. Agglomeration economies, R&D expenditure, and ICT home market size follow the list of the next most important determinants.

The estimated regression model for the integrated circuits and electronic components product group produces coefficient signs that conform to our hypotheses. However, only four explanatory variables are found to be statistically significant: international market access, human capital, R&D expenditure, and cost competitiveness (in order of significance). On the other hand, the coefficients of ICT market size, agglomeration economies, multinational firm activity, and infrastructure are not statistically different from zero. Thus, the estimated model suggests that the above variables do not constitute deterministic factors of export specialization across countries in the given ICT product group.

In both fixed-effects tests the value and statistical significance of the test statistic is particularly high. This finding, coupled with the fact of many insignificant regressors, is an indication that unobserved country-specific factors are particularly important and that other factors account to a large extent for the observed export specialization patterns. In terms of relative importance, international market access is found to exert the strongest influence on the level of export specialization, with a beta coefficient of about 0.63. The estimated elasticity indicates that a 1% increase in the extent of a country's international

market access leads to a 1.04% increase in the export specialization in the integrated circuits and electronic components product group. The next most important determinant is R&D expenditure, with a rather weak impact on the dependent variable, however, as the beta coefficient indicates.

In our third and final model of export specialization, all the parameter estimates have the expected signs. However, two independent variables are found to be statistically insignificant. Hence, according to the estimated regression model, cross-country export specialization within the world economy in telecommunications equipment is a positive function of a country's international market access, ICT home market size, telecommunications-related public infrastructure, agglomeration economies, and R&D; and a negative function of cost competitiveness (in order of statistical significance).

On the other hand, the importance of multinational firm activity within a country and human capital are found to have no effect on the dependent variable. The fixed-effects tests produce high test statistics and significance levels, indicating that unobserved country-specific characteristics and other determinants (not included in the model) explain significantly the cross-country variation in export specialization.

Regarding the relative importance of the determinants, it is evident that no large differences exist in this respect for most regressors. More specifically, four explanatory variables appear to be about equally important in explaining the variation in the dependent variable (agglomeration economies, R&D expenditure, infrastructure, and international market access; in order of importance). Finally, cost competitiveness is found to have the weakest effect on export specialization in telecommunications equipment.

Since to our best knowledge there are no other empirical cross-country studies on ICT export specialization within the world economy[3], no direct comparisons can be made with respect to our estimated determinants and their relative importance and elasticities. However, some loosely related cross-country studies on the determinants of export performance in high-tech products in general seem to agree with some of our findings, such as the importance of R&D (e.g. Braunerhjelm and Thulin, 2008).

The study by Srholec (2007), which comes closest to ours in the sense that it considers only electronics high-tech exports, finds that a country's technological capability (a composite variable that reflects R&D and human capital) is a statistically significant

[3] Several searches in the EconLit database did not return any relevant and directly comparable papers with regard to our empirical study.

determinant of export specialization. However, other factors are found to be relatively more important, which is in line with our findings.[4] Additionally, the significance of international market access is particularly stressed as a determinant of export performance in Redding and Venables (2003); though total exports instead of high-tech exports and are used in their analysis.

6. Conclusions

Our panel-econometric analysis employed in this paper in order to investigate the country-level determinants has revealed some insightful and interesting findings. In particular, although the results across the three ICT product groups are not identical, it has, in general, been found that R&D and human capital have a statistically significant effect on cross-country ICT export specialization.

These deterministic factors are characterized by the theoretical literature as particularly important and driving forces of specialization in ICT and high-tech products. However, according to our findings other determinants are relatively more important than the above two factors for explaining the ICT export specialization across countries. This is especially true for human capital which has been found to have a rather small impact. R&D exerts a much stronger effect compared to human capital and lists among the most important determinants.

The factor that consistently exerts a strong impact on export specialization in all of the three ICT product groups has been found to be international market access; and in two of them this deterministic factor is found to be the most important. Agglomeration economies have also been found to have strong causal effects and be relatively more important than human capital (in all ICT product groups) and R&D expenditure (in two product groups).

Overall, the findings indicate that the determinants associated with the new economic geography are relatively more important than those associated with the traditional comparative advantage framework. Though our econometric analysis does not constitute a formal analysis for testing trade theories, the empirical results seem to suggest that the

[4] Because of the special focus of Srholec's (2007) study on the relevance and importance of intermediate inputs and imports on export performance, the other variables considered by this study are not the same or even comparable to ours. An exception to this could be our international market access variable which also reflects international integration and trade openness. Since international trade can also include trade in intermediate inputs, the significance found for this variable in our analysis may also reflect to some extent the importance of intermediate inputs trade on export specialization, as found in Srholec (2007).

NEG theory explains to a large extent the observed export specialization patterns and is more relevant compared to the comparative advantage theory in the ICT case.

Hence, some policy implications with regard to a country's extent of ICT export specialization seem to be hinted by our empirical analysis. In particular, besides efforts for increasing the national human capital stock and the R&D activities, policies that promote international market linkages, increase the openness of the domestic economy (where involvement in the global ICT production sharing may be particularly important), and promote industrial clustering and agglomeration are expected to have, ceteris paribus, a significant positive effect on ICT export specialization.

Appendix: Variable Descriptions and Data Sources

Variable	Description	Data Source
XS: Export specialization	Balassa index, Equation (2)	Own calculations based on trade statistics from the World Trade Organization's international trade database
RD: R&D	Research & development expenditure as a % of GDP	World Development Indicators (WDI), World Bank
HC: Human capital stock	Researchers in R&D per million people	WDI
CC: Cost competitiveness	Real effective exchange rate index	WDI
ICT: ICT home market size	Total ICT expenditure within a country in current US dollars	WDI
AE: Agglomeration economies	Manufacturing value added in current US dollars	WDI
IMA: International market access	International openness index, Equation (2)	WDI
INF: Infrastructure	Telephone mainlines per 100 people	WDI
MF: Multinational firm activity	Inward FDI stock as a % of GDP	Own calculations based on data from the United Nations FDI database and WDI

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Figure 1: Trends in world ICT exports by main ICT product group, 2000-2007

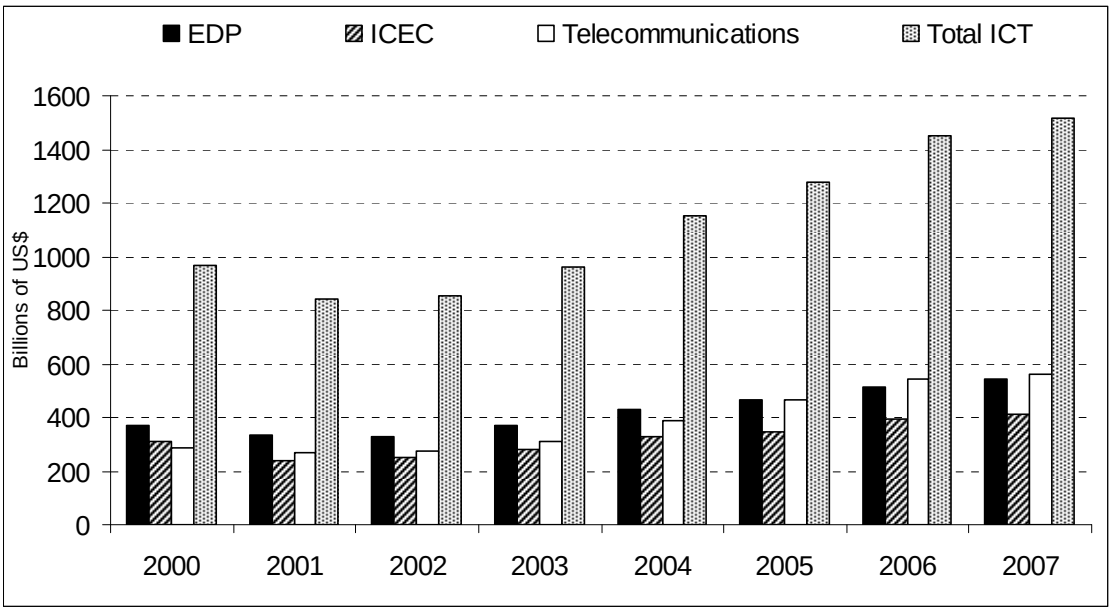

Figure 2: Shares of main ICT product groups in total ICT world exports, 2000-2007

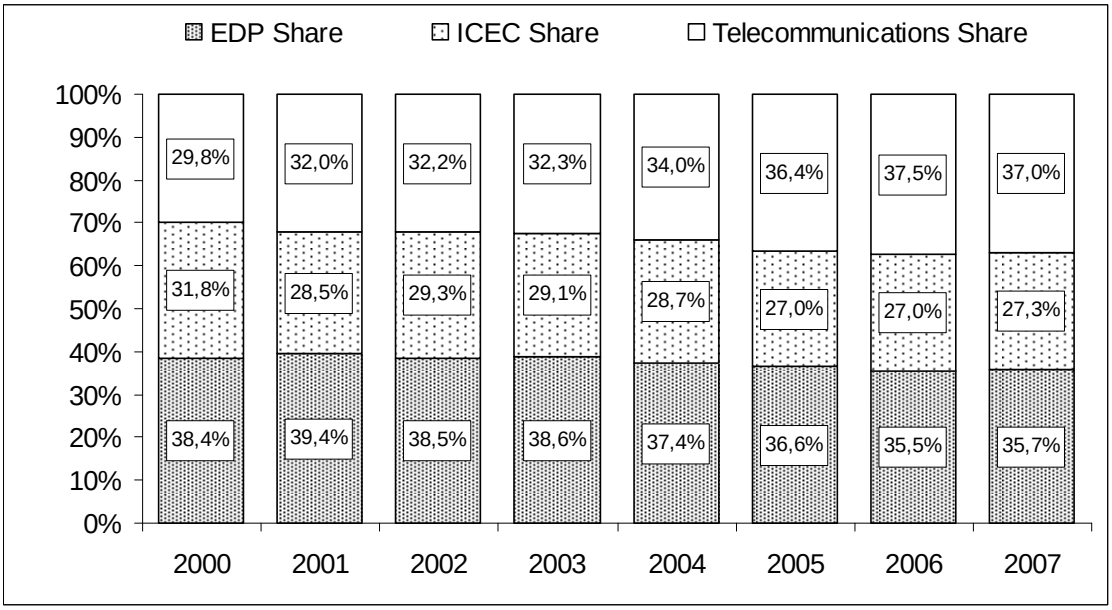

Figure 3: Shares of ICT exports in total manufacturing world exports, 2000 and 2007

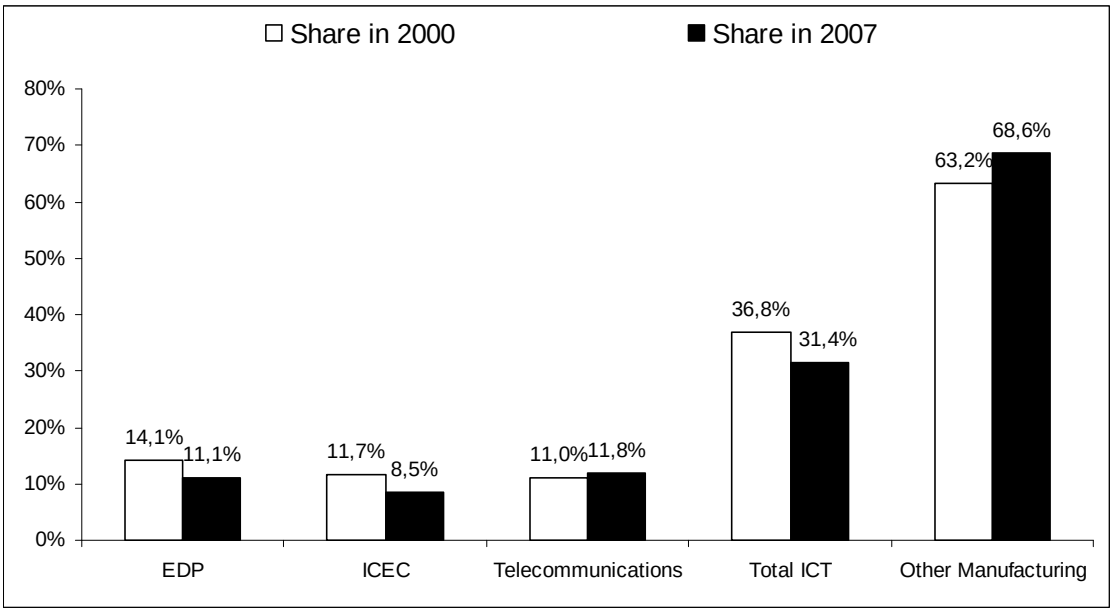

Table 1: Determinants of Export Specialization in three broad ICT product groups (fixed-effects panel estimates)

Independent Variables/ *Statistics*	Electronic Data Processing Machines			Integrated Circuits & Electronic Components			Telecommunications Equipment		
	Regression coefficients	Standardized coefficients	Elasticity	Regression coefficients	Standardized coefficients	Elasticity	Regression coefficients	Standardized coefficients	Elasticity
RD	0.32351 (0.0000)	0.28534	0.65385	0.16857 (0.0245)	0.11190	0.33806	0.30112 (0.0644)	0.24209	0.50563
HC	2.3E-05 (0.0706)	0.03825	0.08064	2.1E-05 (0.0018)	0.02596	0.07215	4.2E-05 (0.4416)	0.06274	0.12054
CC	-0.00387 (0.0432)	-0.02858	-0.41586	-0.00263 (0.0982)	-0.01460	-0.28015	-0.00170 (0.0994)	-0.01143	-0.15163
ICT	1.3E-12 (0.0401)	0.26035	0.12750	3.9E-13 (0.4733)	0.05774	0.03728	9.8E-13 (0.0367)	0.17601	0.07856
AE	9.6E-13 (0.0103)	0.33683	0.22022	2.4E-13 (0.4497)	0.06383	0.05502	8.6E-13 (0.0601)	0.27636	0.16468
IMA	0.00559 (0.0001)	0.43997	0.54640	0.01073 (0.0000)	0.63552	1.04050	0.00324 (0.0007)	0.23224	0.26288
INF	0.01053 (0.0007)	0.13745	0.55604	0.00546 (0.2769)	0.05361	0.28591	0.01968 (0.0408)	0.23406	0.86298
MF	-0.00499 (0.0711)	-0.17321	-0.20084	0.00299 (0.3281)	0.07809	0.11936	2.2E-05 (0.9706)	0.00069	0.00073
AR(1)	0.73275 (0.0000)			0.22874 (0.0109)			0.19505 (0.0184)		
Adj. R^2	0.9788			0.9839			0.9785		
F-statistic	318.84			585.38			309.59		
DW	2.1810			2.0693			1.9621		
F(20, 75)	3.8646 (0.0000)			7.3812 (0.0000)			7.1323 (0.0000)		
$\chi^2(20)$	74.373 (0.0000)			114.24 (0.0000)			111.86 (0.0000)		

Notes: Results for the constant are not shown. *F(20, 75)* and $\chi^2(20)$ are fixed-effects tests. Panel observations (NT)=168, balanced NT=126.