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Abstract

This paper analyses the determinants of the export sophistication of countries using a panel of trade and linked country data covering the 1992-2006 period. The results suggest that the export sophistication of countries is enhanced by capital intensity and engagement in knowledge creation and transfer via investment in education, R&D, foreign direct investment and imports. The effect of natural resource abundance appears to be moderated by the quality of institutions. In the absence of effective institutions, abundance hampers improvements in quality and the structural upgrading of exports yet the existence of abundance can exert a positive impact where good institutions exist. The effects of these determinants vary between sub-country groups of different income levels.

Key Words: Export Sophistication; Factor Endowments; Knowledge Capital

JEL Classification: C23, F14, O30

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1. Introduction

The wave of globalization since the 1980s has seen the significant integration of the world economy. Global trade has increased rapidly during this period. In 2006 the total global exports of goods and services was 11627.5 billion US dollars at the 2000 constant price, which is 4.6 times of that in 1980 at 2520.2 billion US dollars, and 2.8 times of that in 1990 at 4138.9 billion US dollars. The global exports of goods and services to GDP ratio has risen from 18.9 percent to 30.6 percent over the same period. There has been substantial research in this field. However, most of these studies measure exports using export trade volume or the share of export trade in GDP, which in fact only reflect the quantity of trade. The quality of traded goods receives less attention than it deserves. Both the growth experience of some developing countries and empirical results show that what really matters to a country's economic growth in the long-term is not how much it exports, but "what" it exports: that is, export quality and the technology structure (Rodrik, 2006). Recent trade theory also emphasizes that the benefits of trade are derived more from the expansion into new products (Funke and Ruhwedel, 2001; Hummels and Klenow, 2005; Broda and Weinstein, 2006; Amiti and Freund, 2008). Countries which latch on to a set of goods located at the higher end of the quality spectrum tend to perform better (Hausmann, et al., 2007). Therefore, it is important to measure the sophistication level of export products and understand its determinants.

In recent years, several studies have developed different indices to measure export sophistication and have examined the relationship between export sophistication and a country's economic and technology development (Lall, et al, 2005; Rodrik, 2006; Hausmann, et al., 2007; Xu, 2007; Schott, 2008; Van Assche and Gangnes, 2008). Lall, Weiss and Zhang (2005) argue that an export product is more sophisticated the higher the average income of its exporter. They hence define a product's sophistication score[‡] as the trade-share weighted average (the weights being each country's shares of world exports) of income per capita of all the countries exporting this product. Using disaggregated data at SITC 3- and 4-digit levels, they calculate sophistication scores of all traded products and examine the relationship between this index and the existing technological classifications of products. However, taking

[‡] The index is first proposed by Michaely (1984) as income level of export.

each country's share of world exports as a weight when calculating sophistication score may overestimate the role of bigger countries and so neglect export products in which the smaller country has a comparative advantage (Fan, Kwan and Yao, 2006; Hausmann, et al., 2007; Xu, 2007). Rodrik (2006) and Hausmann, et al. (2007) formulate the income/productivity index *PRODY* of a product by taking the comparative advantage of every country's exports as the weight and calculating *PRODY* as the weighted average of per capita incomes of all the countries exporting that product. Furthermore, they construct the productivity level of the country's export (*EXPY)* by taking the weighted average (the weights being the share of each product in a country's exports) of *PRODY* of all export products for that country. They find that per capita income and human capital is positively correlated with *EXPY* but institutional quality is not significantly related to *EXPY* after controlling for per capita income. Schott (2008) estimates an export similarity index (*ESI*) to reflect the relative 'sophistication' of exports and finds China's export overlap with the OECD to be much greater than one would predict, given its size and relative level of development.

These studies have provided useful insights. However, research on the determinants of export sophistication is rare and the existing research calls for improvements in measurement and empirical method. First, the existing literature focuses mainly on the role of GDP per capita and human capital, but omits other important factors that may affect a country's specialization pattern in trade and the sophistication level of exports. Knowledge capital has been widely regarded as a main determinant of economic growth and competitiveness (Romer, 1990). The creation of knowledge capital includes indigenous innovation and external technology transfer. R&D and education is the main source of indigenous innovation, while FDI and import trade are two main channels of technology diffusion. In particular, with imports of the large quantities of intermediate goods with high technology content by export-oriented FDI due to global production fragmentation, export sophistication in some developing countries has risen considerably. Therefore, the effects of these factors are not negligible when examining the determinants of export sophistication of countries. Secondly, if human capital and FDI are introduced into the regression equation as independent variables, then there may be possible causal effects going from export sophistication to these variables in turn, which may result in the endogeneity problem. Finally, the regression equation includes GDP per capita together with human capital and institutional quality as explanatory variables. The latter two factors are often found in literature as important determinants of GDP per capita (eg. Benhabib and Spiegel, 1994; Acemoglu, et al., 2001; Rodrik, et al., 2002; Ulubasoglu and Doucouliagos, 2004). This may lead to the multi-collinearity problem in the model estimation.

This paper aims to examine the determinants of export sophistication in the light of both traditional trade theory and new growth theory using cross-country panel data. It refines the classification of factor endowments and considers the role of education, R&D, FDI and imports. The results show that different factor endowments contribute in different ways to the increase in the technology level of exports. Country size is found to be conducive to the raising of the level of export sophistication. Finally, this paper takes into account the endogeneity between human capital, FDI and the technical upgrading of exports. The empirical model is estimated using both panel OLS and system GMM methods as a robustness check.

The remainder of this paper proceeds as follows. Section 2 proposes a theoretical framework to analyze the determinants of the export technology level. Section 3 discusses model, method and data. Section 4 presents the empirical results. In Section 5 we conclude.

2. Theoretical framework

Trade theory suggests that a country's export bundles should reveal its factor endowments. The principle of comparative advantage dictates that a country should specialize and export those products in which it has a comparative advantage. Therefore countries with more abundant natural resources are expected to export natural resources or resource-intensive products. Countries with abundant labour such as China and India tend to produce and export labour-intensive goods such as toys and apparel. Advanced countries with more capital and superior technology are expected to process and export more sophisticated capital- and technology-intensive products such as pharmaceuticals, chemicals, automobiles and electronic machinery (Xu, 2007; Schott, 2008). The Heckscher-Ohlin model connects countries' relative fundamentals to the mixes of products they can profitably produce and export. A country's factor endowments determine relative costs and the patterns of specialization. Since a country's export baskets are expected to comprise of those goods in which it is the most productive, relative fundamentals will play a pivotal role in its export sophistication. New trade theory suggests that countries are induced to engage in intra-product trade by firms' specialization in distinct horizontal varieties and consumers' preference diversity. An important implication of these models is that the number of product varieties a country can produce and export is a function of its resources endowments (Krugman, 1980; Schott, 2008).

A country's factor endowments can be classified as natural resources, labour, physical capital and knowledge capital along with its institutional quality. Natural resources, for example, land, crude oil and minerals, are the most original factors and the most fundamental inputs to maintain production and technological advances. The hypothesis of the 'resources curse' suggests that lower human and physical capital accumulation and hence productivity growth may be associated with relative resource abundant countries. Empirical research by Audy (1998), Sachs and Warner (1995, 1999, 2001) and Leamer (1999) show that an abundance of natural resources has a detrimental effect on long term economic growth and technical upgrading, although Lederman and Maloney (2003) suggest that Sachs and Warner's conclusion is not robust and depends on the measurement of resource abundance and estimation technique used. Research by Hausmann, et al. (2007) confirms the negative association between a country's land area and its export sophistication level.

The labour force and physical capital have long been regarded as the key inputs to productive activities. In addition, new growth theory emphasizes that knowledge capital is the engine and stimulus of economic growth in the long run (Romer, 1990). Knowledge capital either results from indigenous knowledge creation, or derives from the access, transfer and assimilation of international knowledge through participation in international trade and openness to foreign direct investment. Human capital and R&D are recognized as two important factors which contribute to indigenous knowledge creation (Ascari and Di Cosmo, 2004). Schott (2008) defines skill abundance as the share of the population with secondary or higher level of education in the total population, and finds that export similarity of a country with OECD countries group increases with the enhancement of its per capita GDP or skill abundance.

Imports and FDI are two channels of international technology transfer. They also spur on the development of industrial technology in related domestic industries through vertical linkage effects (Coe and Helpmann, 1995; Javorcik, 2004). A country's export bundles represent the set of the most competitive products. Therefore, the contribution of imports and FDI to technological progress in a country will be reflected in the export sophistication of the host country directly or indirectly. Moreover, due to the fragmentation of the global production chain and increasing global outsourcing, some developing countries started to export technology-intensive products. Such exporting does not show that these countries have the capability to produce these "sophisticated" products: they in fact export these goods simply through processing and assembling high-technology intermediate imports (Xu, 2007). Therefore import trade affects a country's export sophistication through imports of intermediate goods, which is closely related to export processing activities. All this, to a certain degree, leads to the rise of the share of high-technology product exports in the total exports of developing countries: this ratio has increased from 11% in the middle of the 1990s to reach 19% during the period 2002-2004 (International Monetary Fund, 2008).

In addition to the factor endowments discussed earlier, institutional quality may play an important role in moderating the effects of these factors on export sophistication of countries. For example, positive trade policies such as export rebates can encourage export and expand the variety and range of exporting products. On the other hand, import tariffs can distort the mechanism of product price and drive a wedge between the domestic price of a good and its price on world markets, which can result in the misallocation between resource endowments and firms' production (Schott, 2008). Lo and Chan (1998) argue that the Chinese export structure cannot be explained completely by its comparative advantage: government technology-oriented policies have also played an important role.

3. Model, Data and Method

3.1 Model

Following Hausmann, et al. (2007), we assume a two-sector economy: the traditional sector and the modern sector. The traditional sector only produces single homogeneous goods which are mainly used for the domestic consumption, and the modern sector produces a variety of products. In general, the modern sector has a relatively high technology level. One country exports its most competitive products in the world market. The basic input factors of the modern sector include natural resources, labour and physical capital. The production function is given by

$$Y = AL^{\alpha} K^{\beta} N^{\gamma} \quad (1)$$

where *L*, *K*, *N* denote labour, capital and natural resources, respectively. With respect to these input factors, the output exhibits constant returns to scale: that is, $\alpha + \beta + \gamma = 1$. *A* is a parameter of the technical level involved in combining these factors in production, and is distributed uniformly over the range $[0, \hat{A}]$. $\hat{A}$ is determined by a country's skill endowments. Following Fagerberg (1988) and Sterlacchini (2008), we assume that $\hat{A}$ is the multiplicative function of the knowledge taken from domestic (*D*) and foreign (*F*) sources, the capability to reap the benefits of both kinds of knowledge (*I*) , and a constant (B). The capability to exploit both external and internal knowledge is shaped by the institutional, social and cultural features of each country (Sterlacchini, 2008). The accumulation of domestic knowledge is usually promoted by R&D and education whilst foreign knowledge capital is mainly acquired though FDI and imports. Omitting time suffixes, the basic function is then $\hat{A} = BD^{\lambda_D} F^{\lambda_F} I^{\lambda_I}$, where *B* incorporates the effect from other factors which possibly affect technical parameters. λ_i (*i* stands for *D*, *F* or *I*, respectively) represents the production elasticities of knowledge capital. The bigger $\hat{A}$ is, the higher the level of the economy's production frontier: hence the economy has more capacity to produce goods of higher productivity. No investors know with certainty whether the new products will ultimately have a high-productivity or a low-productivity level, and only know *ex ante* that *A* obeys a uniform distribution over the range $[0, \hat{A}]$. However once the new products have been developed, *A* becomes generally known. Therefore other firms can imitate products without incurring additional "discovery" costs but at a fraction θ ($0 < \theta < 1$) of the incumbent's productivity. We assume every investor can run only one project. So having developed his own products, the investor has the choice of continuing his own goods or emulating the products with highest productivity. The investor will fix his choice by comparing productivity (A_i) of his own goods to that of the most productive good which he will imitate. If $A_i > \theta A^{\max}$, the investor will choose to stick with new good developed by himself, and otherwise he will imitate the $A^{\max}$-product. Additionally, the expectations of $A^{\max}$ depend on the productivity frontier and the number (*m)* of firms which engage in investing in the modern sector: that is $E(A^{\max}) = \frac{m \cdot \hat{A}}{m+1}$. Since the technical parameter *A* is distributed uniformly over $[0, \hat{A}]$, following Hausmann, et al. (2007), the probability and expected technical level of investors sticking with their own initial projects are, respectively:

$$prob(A_i \geq \theta A^{\max}) = 1 - \frac{\theta m}{m+1} \qquad (2)$$

$$E(A_i \mid A_i \geq \theta A^{\max}) = \frac{1}{2}\hat{A}[1 + \frac{\theta m}{m+1}] \qquad (3)$$

Similarly, the probability and expected technical level for the firms emulating the $A^{\max}$-products are, respectively, as follows:

$$prob(A_i < \theta A^{\max}) = \frac{\theta m}{m+1} \qquad (4)$$

$$E(A_i \mid A_i < \theta A^{\max}) = \hat{A}\frac{\theta m}{m+1} \qquad (5)$$

Combining these equations, we can derive the following expectation for the technical parameter *A* in modern sector:

$$E(A) = \frac{1}{2}\hat{A}[1 + (\frac{\theta m}{m+1})^2] \qquad (6)$$

Introducing (6) into (1) and combining the expression of $\hat{A}$, we can derive the expected output as follows:

$$E(Y) = \frac{1}{2}B[1 + (\frac{\theta m}{m+1})^2]D^{\lambda_D}F^{\lambda_F}I^{\lambda_I}L^{\alpha}K^{\beta}N^{\gamma} \qquad (7)$$

Due to constant returns to scale, the expected labour productivity level is

$$E(Y)/L = \frac{1}{2}B[1 + (\frac{\theta m}{m+1})^2]D^{\lambda_D}F^{\lambda_F}I^{\lambda_I}(K/L)^{\beta}(N/L)^{\gamma} \qquad (8)$$

The above formula indicates that the expected productivity of the modern sector depends on relative capital and natural resources endowments, domestic and foreign knowledge capital, the capability to reap the benefits of both kinds of knowledge, and also the number of enterprises which engage in development and cost discovery of new products. Assuming the modern sector is the export sector of an economy, *E(Y)/L* can be proxied by export sophistication index (*EXPY*) defined as the productivity level of a country's export basket. Therefore, given our theoretical analysis in Section 2, replacing *E(Y)/L* with *EXPY* in equation (8) and taking logarithm, we can specify the basic empirical model as follows:

$$\begin{aligned} LEXPY_{it} &= \beta_0 + \beta_1 Lrcapl_{it} + \beta_2 Lrlandp_{it} + \beta_3 Lh_{it} + \beta_4 Rrdg_{it} + \beta_5 Rfdig_{it} \\ &+ \beta_6 Rimpg_{it} + \beta_7 Lpop_{it} + \beta_8 I_{it} + v_i + u_t + \varepsilon_{it} \end{aligned} \quad (9)$$

where subscript i represents the country, t denotes the period, v_i and u_t indicate cross-section fixed effect and period fixed effect, respectively. ε_{it} is random error term, which is not correlated to v_i, u_t or the independent variables. *L* represents the natural logarithm of corresponding variables, and *R* indicates that the value of the corresponding variable is in the form of a ratio. The variable *rcapl* refers to the capital-labour ratio whilst *rlandp* represents land area per capita: both of these variables mainly reflect the relative factor endowments of a country's natural resources, physical capital and labour force. Physical capital is proxied by gross capital formation. *h* is human capital, which is measured by the gross tertiary enrolment rate. *Rrdg* is the proportion of R&D expenditure in GDP. These two variables reflect the domestic knowledge endowment of a country. *Rfdig* and *Rimpg* are the proportion of annual foreign direct investment stock (inward flow) and the proportion of imports of goods and services in GDP, respectively. *Pop* denotes the population, reflecting the size of the country. The variable *I* is institutional quality, proxied by the 'rule of law index' which is a commonly used index of institutional quality (see next section for definition).

3.2 Method and data

The dependent variable (*LEXPY*) is the natural logarithm of the export sophistication index. The main proxies of export technology level include the export sophistication index of Lall, Weiss and Zhang (2005) as amended and developed by Rodrik (2006) and Hausmann, et al. (2007). This paper uses the amended index that uses comparative advantage of each country's export product as a weight for the calculation of the export sophistication index

(*PRODY*) since it circumvents the possible bias caused by the country's export scale. The sophistication level of a country's export bundle (*EXPY*) can be calculated via the weighted average of the sophistication index of all export products in this country. The basic formula is as follows:

$$EXPY_c = \sum_i \left(\frac{x_{ci}}{X_c} PRODY_i\right) \;,\; PRODY_i = \sum_c \left\{\left[(x_{ci} / X_c) / \sum_n (x_{ni} / X_n)\right] Y_c\right\} \qquad (10)$$

where *i*, *j* denote products. *c*,*n* denote countries. x_{ji} refers to the value of exports of product *i* in country *j* (*j*=*c*, *n*). $X_j = \sum_i x_{ji}$ is the total exports of country *j*. Taking within-product sophistication into consideration, Xu (2006) makes a quality adjustment of the index *PRODY* by using relative unit values of export products to reflect quality differences within products. Van Assche and Ganges (2008) argue that, due to international production fragmentation and trade in intermediate products, the existence of processing trade will cause the export sophistication level of products to be overestimated. They use the production data, not exports, to calculate product sophistication index, and thus can minimize the impact of the processing trade to a greater extent. Although Xu (2006) and Van Assche and Ganges (2008) consider the impact of quality difference within products and processing trade, which make their indexes better than that of Rodrik (2006), their indices are largely limited by the missing of data of production and import and export volume of each country in practical applications. As a result, this paper employs the index of Rodrik (2006) to measure the sophistication level of a country's exports: we should, however, bear in mind the limitations of this measure.

We use the panel GLS method of fixed effect (FE) or random effect (RE) for the estimation. We determine which method is preferred according to the estimates of the Hausman-test. Robust standard errors are calculated to eliminate potential heteroscedasticity and autocorrelation of the panel data. However, there is a possible endogeneity problem between some of the independent variables such as human capital and foreign direct investment and the dependent variable. The empirical literature often finds significant endogeneity between human capital, foreign direct investment and technological progress (Li and Liu, 2005; Fu, 2008). Hausmann, et al. (2007) also argue that "it may be difficult to give the relationship with human capital a direct causal interpretation, since the causal effect may go from *EXPY* to human capital rather than vice versa". In order to deal with the potential problem of endogeneity, we employ a system generalised method of moments (GMM) regression technique for the estimation (see, inter alia, Hansen (1982); Arellano and Bover (1995); Blundell and Bond (1998)). We add the initial levels equation into the equation system, and use lagged differences of endogenous variables to instrument the endogenous variables in the levels equation. We also include infrastructure and financial development and a lagged variable of *Rfdig* as exogenous variables to instrument endogenous variables *Lh* and *Rfdig*. Infrastructure is indexed by data on telephone mainlines per 100 people (*Ltelep*) taken from the World Development Indicators (WDI) database of the World Bank. Financial development is commonly measured by domestic credit to the private sector as a share of GDP (*Rdcpg*), again taken from the WDI database. We formally test whether the assumption of endogeneity is borne out by the data at hand and whether our instruments are relevant in the sense that they exhibit sufficiently strong correlations with the potentially endogenous variables. We carried out an autocorrelation test to determine the initial order of lags to ensure the validity of instrument variables. We also carefully tested for the appropriateness of the instrumental variable candidates using Hansen's J test for overidentifying restrictions. Reassuringly, we found that our instruments are appropriate on all counts.

Data

Data used in this paper includes disaggregated export data at the SITC 3-digit level across 171 countries or regions over the 1992-2006 period. There are in total 239 products according to the SITC classification at the 3-digit level. The export data are taken from the International Trade Classification and Statistics Database of UNCTAD. Data on GDP per capita for all countries or regions are derived from WDI Database, and measured at 2000 constant US$ and PPP prices.

The data on population, labour, land area, human capital and the proportion of R&D expenditure in GDP again come from the WDI database. GDP, capital formation, foreign direct investment stock (inward flow) and import data come from the UNCTAD database. The data on institutional quality are collected from the World Bank's WGI (Worldwide Governance Indicators) database, which reports the rule of law, government efficiency and other six institutional quality indexes in the years of 1996, 1998 and 2000-2006. Each index ranges from -2.5 to 2.5. A higher value represents better governance (Kaufmann, et al., 2008). The monetary unit of the original data is current dollar prices so we deflate all these data using the U.S. consumer price index (CPI) with 2000 as the base year. Since the data for some variables such as the proportion of R&D expenditure in GDP, human capital etc. are unavailable in the main years of sampling period for many countries, these countries are dropped from the initial samples. The final sample used for the regression analysis thus includes only 65 countries (see Appendix A). The descriptive statistics and correlation coefficient matrix of all the variables are shown in Table 1. Per capita GDP is positively correlated to capital-labour ratio, institutional quality, human capital and R&D. The correlation coefficients between per capita GDP with both the capital-labour ratio and institutional quality are particularly high, being above 0.95 and 0.81. Therefore, as discussed earlier, if per capita GDP is included as an independent variable, there will be a serious multi-collinearity problem in the model estimation, leading to biased estimators.

[Insert Table 1 here]

Figure 1 illustrates the average log values of the export sophistication score (*LEXPY*) for all sample countries and sub-groups classified by income[§]. In general, the export sophistication index of all country groups rises steadily over the sample period. The average *LEXPY* of all countries rises significantly during the period 1992-2006, with the logarithm rising from 8.53 in 1992 to 9.17 in 2006. The average export sophistication of high-income countries is significantly higher than those of middle and low income countries.

[Insert Figure 1 here]

Figure 2 shows the average *LEXPY*s of China, India, Japan, US, E7[**], G7 and OECD countries. The average *LEXPY*s of all these countries or groups clearly rise over the sample period. The average export sophistication of G7 countries is always higher than that of OECD and E7 countries. Among G7 countries, the export sophistication index of Japan has been consistently higher than the US. Although China's export sophistication was lower than the

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[§] The World Bank divides all the countries or territories into low-income, lower middle-income, upper middle-income and high-income groups on the basis of GNI per capita in 2006.

[**] The E7 Group includes seven newly industrialized countries: Brazil, Russia, India, China, Indonesia, Mexico and Turkey. The G7 includes the United States, Britain, France, Germany, Italy, Canada and Japan.

average of the E7 before 1994, it upgraded rapidly and has been higher than the E7 average since 1995. The export sophistication of China steadily converged to that of the OECD, the G7 and the US, and even exceeded the average of OECD countries in 2006. The average annual export sophistication of India is significantly lower than that of China.

[Insert Figure 2 here]

4. Empirical Results

Empirical analysis of all countries

Empirical results of panel GLS estimation are presented in Table 2. All the estimations include fixed period effects. Column 1-2 reports estimates of the basic model; Columns 3-4 include country size and institutional quality, progressively. Column 5 presents the estimated results using instrumental variables. The Hausman test statistic suggests that the random effects model is preferred to the fixed effect model. The estimated coefficient of the capital-labour ratio is positive and statistically significant. The result is robust across different models suggesting that an increase in capital intensity leads to the higher export sophistication of countries. The coefficients of land area per capita are negative and statistically significant in all specifications except the fixed effects model, supporting the 'resource curse' hypothesis that abundance in natural resources hinders a country's efforts in skills accumulation and industry upgrading. Knowledge creation activities such as human capital and R&D investment show a consistent and robust positive impact on export sophistication. Foreign direct investment and imports also have shown a robust significant positive effect on export sophistication. Country size also demonstrates a significant positive effect on export sophistication, as expected. However, the estimated coefficient of institutional quality as proxied by the rule of law index is not statistically significant. The estimated results using instrumental variable (IV) method are broadly consistent with the estimates from panel GLS.

[Insert Table 2 here]

Table 3 illustrates the system GMM estimations in which we refine the model specifications by considering the correlation among explanatory variables. All the estimations include fixed period effects. The autocorrelation tests of the residual show that there is not significant first-order autocorrelation. Given the missing data and correlation between the variable *I* and other variables such as *Lrcapl*, *Lh* and *Rrdg*, we run separate regressions excluding and including the variable *I*. The estimated results are reported in columns 1-3 and column 4-5, respectively. Moreover, due to the significant correlation between variables *Rimpg* and *Rfdig*, and between *Rrdg*, *Lrcapl* and *Lh*, we also experimented with different specifications dropping *Rimpg*, *Rrdg* and *Lrcapl* from the full equation as a robustness check. Capital intensity shows a significant positive impact on the sophistication level of exports. This result is robust across different methods and model specifications. The estimated coefficient of land area per capita is negative and significant. This result is again robust across different models. This evidence is consistent with the predictions of the resource curse hypothesis that the richer a country is in natural resources endowment, the more likely it is to become locked in low-skill, natural-resource-based industries, underrate the importance of good economic policies, and overlook the need for good education and human capital accumulation (Gylfason, 2001). This finding is also consistent with findings by Hausmann, wt al. (2007) on the association between land area and export sophistication of countries.

[Insert Table 3 here]

The estimated coefficients of human capital intensity are positive and statistically significant. The results are robust across all model specifications except for one case, which is likely due to the high correlation between human capital and other variables such as capital intensity and institutional quality. Dropping variables *Rimpg*, *Rrdg* and *Lrcapl* alternatively from the full model, the estimated coefficients of *Lh* become more significant and of bigger size. The estimated coefficients of R&D intensity are also positive and statistically significant. The results are again robust across all model specifications. All these findings suggest that human capital and R&D are two key factors in the upgrading of the export sophistication of countries. FDI and import trade appear to have a significant positive empirical effect on export sophistication. The results are also robust across different model specifications, suggesting the importance of external knowledge in the increase of the export sophistication of countries.

Finally, country size exerts a positive impact on export sophistication. This is consistent with the prediction of new trade theory which suggests that the number of horizontal varieties produced by a country is a function of its economic scale (Krugman, 1980; Schott, 2008; Hummesl and Klenow, 2005). It is also consistent with findings by Hausmann, et al. (2007) which proxy country size using population.

The estimated coefficients of institutional quality proxied by the rule of law index are not statistically significant, even after dropping some of the explanatory variables (*Lrcapl*, *Rrdg* and *Rimpg*) which are significantly correlated with institutional quality. On the other hand, better institutional quality can allow a country to elude the adverse effects which accompany and abundance of resources and so exploit the margins of those resources effectively (Gylfason, 2001). Natural resources may impact on economic growth through both "positive" and "negative" channels, which critically depend on the nature of the learning process involved in exploiting and developing natural resources (Stijns, 2005). For example, Norway is the world's second largest oil-exporting country behind only Saudi Arabia. Canada and Australia are also resource-rich countries. These countries have shown better growth performance and higher export sophistication. Therefore, we also experiment in model 6 to include an interaction term of institutional quality and endowment in natural resources. The estimated coefficient of the interaction term is positive and statistically significant, which indicates that institutional quality moderates the effect of natural resources on export sophistication. Better institutional quality can effectively facilitate the usage of resource endowments and upgrading of the export sophistication of countries. This is similar to the findings in Mehlum et al. (2006) that the resource curse depends on the quality of institutions and so only appears in the countries with poor institutional quality.

Empirical analysis of sub-groups by income level

identify the different impacts of determinants on export sophistication among countries of different income levels, we further classify all sample countries into two sub-samples as follows: a high and middle (HM) income group (including the upper-middle and high income groups, a total of 46 countries or regions) and a low and middle (LM) income group (including low and lower-middle income groups, a total of 19 countries or territories). Details of the country classification and list of countries in each category are given in Appendix A. Table 4 reports the estimated results from these country groups.

[Insert Table 4 here]

For the HM income country group, the estimated coefficient of the capital-labour ratio is significant and positive while the coefficient of land area per capita is still negative, but not significant. The result, however, is reversed for the LM income group. The estimated coefficient of the former is positive but not statistically significant, while the estimated coefficient of the latter is significantly negative. In other words, countries in the HM income group are abundant in capital endowment (the average of capital per worker for this group is about $6966), and capital intensity has played a significant role in their export sophistication. On the other hand, countries in the LM group are lacking in capital (the average capital per worker is only $689). Therefore, the capital-labour ratio is not a significant determinant of their export sophistication. Moreover, the estimated coefficient of land area per capita is significantly negative and its absolute value is much larger than that for all sample countries as reported in Table 3. This suggests that the natural resource curse may exist in low income countries, but not in high income countries. Human capital is found to play a positive role in upgrading export sophistication level in the LM income group. However, the effect of R&D is not statistically significant in these countries. On the contrary, R&D plays a statistically significant role in the upgrading of export sophistication in high income countries, but higher education does not show any statistically significant effect in these countries. FDI contributes to export sophistication in both the LM and the HM countries. Imports have a robust and statistically significant effect in the LM countries yet not in the HM country group. Country size shows a significant positive effect in both country groups, but its impact on export sophistication is larger in the LM group than in the HM group. Finally, the poor institutional quality in LM countries proves to be a significant barrier to the upgrading of export sophistication. However, good institutional quality can significantly eliminate the resource curse in this group of countries and ensure that the benefits from natural resources are realised.

5. Conclusions

In recent years, considerable research has been devoted to the construction of indices to measure export sophistication and the quality of exports. However, their determinants have not been fully explored so far. This paper has tried to fill this gap by examining the determinants of export sophistication in the light of traditional and new trade theory using a linked cross country panel dataset over the 1992-2006 period. It refines the classification of factor endowments by including knowledge capital in addition to land, capital and labor. We measure the export sophistication of countries using disaggregated trade data for 171 countries or regions over the 1992-2006 period, and then link the estimated sophistication index to a cross country dataset to analyze determinants using a system GMM method. Findings from the research suggest that one important determinant of export sophistication is the capital-labour ratio of a country: the higher this ratio ie. the more abundant is capital compared to labour, the more likely a country is to produce and export more sophisticated goods. This is particularly the case in the HM income country group. However, in the LM income country group, increases in capital intensity do not appear to enhance export sophistication of these countries.

In general, natural resources have a negative impact on the export sophistication of countries. It appears to reduce a country's motivation in physical and human capital accumulation and industry upgrading, which leads the country to be locked into natural resource-based and low-end technological industries. Hence these countries export less sophisticated, low value-added resource-intensive products. This result is consistent with the findings of Hausmann, et al. (2007). This resource curse is particularly significant in the low income country group. However, institutional quality appears to constitute an important moderator mediating the impact of natural resources on export sophistication. Results from this research show that in countries with higher institutional quality, natural resources tend to generate a significant positive effect on export sophistication. This mediating effect of institutional quality is particularly significant in the low income country group. In fact, natural resources are not intrinsically a barrier to growth: rather, they merely increase the probability that governments and the private sector will exhibit "inertia", becoming dependent on natural resources, which consequently results in a path dependent trajectory towards inefficient economic growth. Better policy and institutional specification can reduce this negative effect. The economic development of countries such as Australia, Canada, Finland, Sweden and the USA benefited from abundant natural resources (de Ferrantiet et al. 2002). This also reinforced the argument of Mehlum et al. (2006) that, as suggested by the findings of this paper, the resource curse only appears in the countries with poor institutional quality. Of course, further research is needed using more accurate measures of natural resource abundance and institutional quality.

With regard to knowledge capital or skills endowment, this paper differentiates this factor into internal knowledge and external knowledge transfer. Human capital and R&D serve as the important sources of indigenous knowledge creation, which directly contribute to the rise of export sophistication of countries. The effect of education is significant in the low income country group, while the effect of R&D is significant in high income countries. As the main channels of international knowledge transfer, FDI and imports are found to have significantly positive impact on the export sophistications of countries. The effect of FDI has been robust in different models and in different country groups. The effect of imports is more robust in low income countries. To note, however, FDI and imports may impact on export sophistication of host countries via different channels. In the long term, they can accelerate the rise of export sophistication by the diffusion of external knowledge. On the other hand, as a result of global production fragmentation and outsourcing, they also have short-term effects on export sophistication of host countries. Some developing countries import a large number of technology-intensive intermediate goods through FDI and imports, and export sophisticated final products after simply assembling and processing. Thus FDI and imports only promote a rise in the export technology level in the short run. Therefore, a country's exports may not truly reflect the skill and factor endowment embodied in domestic production activity but only exemplify the skill and factor endowment of origin countries from which the intermediate products are imported (Van Assche and Gangnes, 2008). Therefore, the presence of processing trade may cause the technology level of export to be overestimated. Further research is needed to eliminate the impact of processing trade and further explore and compare the different effects of the various determinants.

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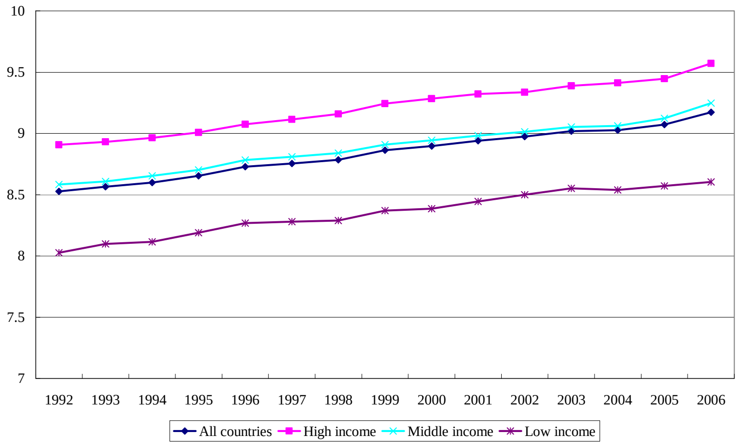

Figure 1 Averages of export sophistication for all sample countries and groups by income level

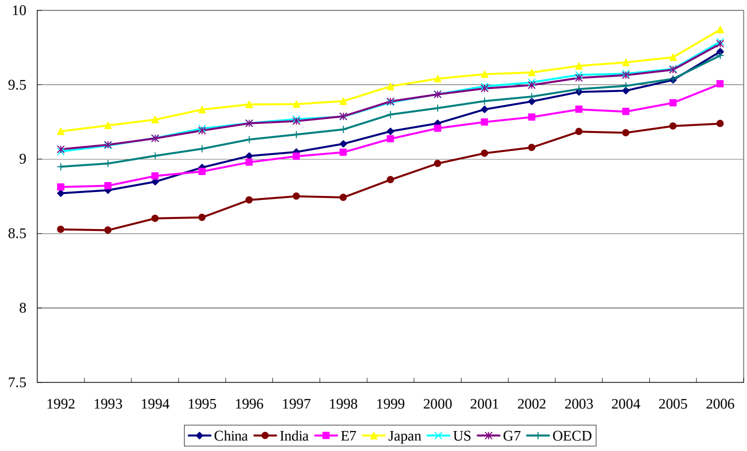

Figure 2 Annual averages of export sophistication of selected countries and country groups

Table 1 Correlation coefficients matrix and descriptive statistics for all variables

	LEXPY	*Lrcapl*	*Lrlandp*	*Lh*	*Rrdg*	*Rfdig*	*Rimpg*	*Lpop*	*I*	*Lpgdp*
LEXPY	1									
Lrcapl	0.6125	1								
Lrlandp	-0.2172	-0.0811	1							
Lh	0.6294	0.6519	0.1477	1						
Rrdg	0.4847	0.6666	-0.1	0.4765	1					
Rfdig	0.3696	0.1789	0.0473	0.1696	-0.1381	1				
Rimpg	0.1164	-0.0395	-0.0525	0.1112	-0.171	0.3976	1			
Lpop	0.1643	-0.0897	-0.2361	-0.1224	0.0734	-0.2621	-0.5276	1		
I	0.4554	0.8388	-0.0155	0.4782	0.6867	0.122	0.0067	-0.1439	1	
Lpgdp	0.6745	0.9586	-0.0424	0.7422	0.6507	0.1844	-0.0122	-0.1251	0.8157	1
Mean	9.0659	-5.9941	-4.0444	3.4066	1.1739	24.5342	39.1109	16.4334	0.4746	9.1133
Std. Dev.	0.3760	1.3803	1.2781	0.8558	0.9602	22.3352	19.5997	1.6042	0.9712	0.9711
Observations	975	965	975	975	770	967	966	975	520	974

Table 2 Empirical Results from Panel GLS and Panel IV Estimations

	1	2	3	4	5
	RE model	**FE model**	**RE Model**	**RE Model**	**IV Model**
Constant	9.0683***	8.9241***	8.2654***	8.1589***	7.5108***
	(0.1095)	(0.3066)	(0.2337)	(0.2613)	(0.3827)
Lrcapl	0.0453***	0.0320***	0.0509***	0.0537***	0.0493***
	(0.0075)	(0.0086)	(0.0074)	(0.0117)	(0.0133)
Lrlandp	-0.0690***	-0.1095	-0.0513**	-0.0497***	-0.0533***
	(0.0187)	(0.0741)	(0.0165)	(0.0165)	(0.0182)
Lh	0.0764***	0.0579***	0.0830***	0.0909***	0.1304**
	(0.0118)	(0.0125)	(0.0117)	(0.0162)	(0.0558)
Rrdg	0.0187**	0.0057	0.0212***	0.0397***	0.0335*
	(0.0078)	(0.0082)	(0.0077)	(0.0148)	(0.0174)
Rfdig	0.0008***	0.0008***	0.0009***	0.0008**	0.0013***
	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0005)
Rimpg	0.0011**	0.0015***	0.0014***	0.0017***	0.0016**
	(0.0005)	(0.0005)	(0.0005)	(0.0006)	(0.0007)
Lpop			0.0525***	0.0557***	0.0579***
			(0.0137)	(0.0140)	(0.0149)
I				0.0128	0.0107
				(0.0217)	(0.0222)
Period-effect	Yes	Yes	Yes	Yes	Yes
Overall R-square	0.6152	0.4864	0.7025	0.7540	0.7643
Num of Obs	765	765	765	452	438
Num of Countries	65	65	65	65	65
Hausman Test	17.22		10.65	12.89	13.28
(H0: random effects)	(0.6383)		(0.9350)	(0.4563)	(0.4261)

Notes:

(1) Standard errors are provided in parentheses below the respective estimated coefficients. *, ** and *** indicate respectively significance levels of 10%, 5% and 1%.

(2) The corresponding parenthetical values for the Hausman test are *p*-values.

Table 3 Empirical Results from System GMM Estimation for All Sample Countries

	1	2	3	4	5	6
Constant	7.9096*** (0.4094)	8.0746*** (0.3716)	7.0502*** (0.2846)	8.1850*** (0.5562)	6.9395*** (0.3583)	8.0053*** (0.4539)
Lrcapl	0.0938*** (0.0240)	0.0869*** (0.0190)		0.1446*** (0.0444)		0.1382*** (0.0387)
Lrlandp	-0.0349** (0.0168)	-0.0552*** (0.0139)	-0.0532*** (0.0157)	-0.0340* (0.0174)	-0.0588*** (0.0173)	-0.0518*** (0.0196)
Lh	0.0940* (0.0535)	0.1531*** (0.0462)	0.1588*** (0.0453)	0.0819 (0.0623)	0.1644*** (0.0615)	0.0958* (0.0562)
Rrdg	0.0511** (0.0253)		0.1031*** (0.0273)	0.0611** (0.0307)	0.0671** (0.0314)	0.0584** (0.0283)
Rfdig	0.0035*** (0.0009)	0.0037*** (0.0007)	0.0050*** (0.0009)	0.0036*** (0.0009)	0.0049*** (0.0008)	0.0037*** (0.0009)
Rimpg	0.0030** (0.0014)			0.0032** (0.0014)		0.0031** (0.0014)
Lpop	0.0774*** (0.0127)	0.0573*** (0.0114)	0.0538*** (0.0130)	0.0813*** (0.0126)	0.0636*** (0.0144)	0.0824*** (0.0122)
I				-0.0685 (0.0463)	0.0522 (0.0358)	
*I*Llandp*						0.0170* (0.0098)
Period-effect	Yes	Yes	Yes	Yes	Yes	Yes
Num of Obs.	765	959	770	452	457	452
Num of Countries	65	65	65	65	65	65
AR(1) Test	-1.17 (0.241)	-0.75 (0.451)	-0.94 (0.349)	-0.87 (0.385)	-0.38 (0.701)	-0.90 (0.369)
Hansen Test	39.04 (1.000)	46.99 (1.000)	47.03 (1.000)	49.66 (1.000)	57.50 (1.000)	52.43 (1.000)

Notes:

(1) Standard errors are provided in parentheses below the respective estimated coefficients. *, ** and *** denote respectively significance levels of 10%, 5% and 1%.

(2) AR(1) provides the statistics for serial correlation test. Hansen test is the tests of overidentifying restrictions for instrumental variables. The corresponding parenthetical values for these specification tests are *p*-values.

(3) All results are from robust one-step system GMM estimation. Endogenous variables are *Lh* and *Rfdig*.

Table 4 Empirical Results for Sub-samples by Income Level: System GMM Estimates

	HM Group			LM Group		
Constant	7.8828***	8.2083***	7.9328***	6.3173***	6.2135***	5.8745***
	(0.4240)	(0.4815)	(0.3887)	(0.6590)	(0.5290)	(0.5539)
Lrcapl	0.0871***	0.1292***	0.1088***	0.0097	0.0438	0.0408
	(0.0267)	(0.0442)	(0.0349)	(0.0460)	(0.0533)	(0.0559)
Lrlandp	-0.0171	-0.0234	-0.0405	-0.0968***	-0.0933***	-0.0922***
	(0.0167)	(0.0187)	(0.0254)	(0.0314)	(0.0336)	(0.0356)
Lh	0.0248	0.0607	0.0737	0.1684***	0.1416***	0.1462***
	(0.0718)	(0.0706)	(0.0760)	(0.0320)	(0.0369)	(0.0357)
Rrdg	0.0557**	0.0603*	0.0567*	-0.0023	-0.0185	-0.0169
	(0.0250)	(0.0315)	(0.0295)	(0.0739)	(0.0629)	(0.0608)
Rfdig	0.0022*	0.0030***	0.0033***	0.0037***	0.0035***	0.0034***
	(0.0012)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Rimpg	0.0031**	0.0026	0.0023	0.0054***	0.0067***	0.0064***
	(0.0014)	(0.0017)	(0.0017)	(0.0021)	(0.0020)	(0.0021)
Lpop	0.0685***	0.0644***	0.0671***	0.1077***	0.1249***	0.1223***
	(0.0149)	(0.0157)	(0.0155)	(0.0227)	(0.0178)	(0.0185)
I		-0.0643			-0.1155**	
		(0.0584)			(0.0532)	
I Lrlandp*			0.0117			0.0220*
			(0.0127)			(0.0128)
Period-effect	Yes	Yes	Yes	Yes	Yes	Yes
Num of Obs.	591	338	338	174	114	114
Num of Countries	46	46	46	19	19	19
AR(1) Test	-2.36	-0.88	-0.78	-0.51	-1.13	-1.17
	(0.018)	(0.379)	(0.437)	(0.611)	(0.260)	(0.242)
AR(2) Test	-0.35					
	(0.725)					
Hansen test	25.83	31.36	30.20	0.00	2.64	2.58
	(1.000)	(1.000)	(1.000)	(1.000)	(1.000)	(1.000)

Notes:

(1) Robust standard errors are provided in parentheses below the respective estimated coefficients. *, ** and *** indicate respectively significance levels of 10%, 5% and 1% respectively.

(2) AR( ) provides the statistics for serial correlation test. The Hansen test statistics report the results of tests of overidentifying restrictions for instrumental variables. The corresponding parenthetical values for these specification tests are *p*-values.

(3) All results are from robust one-step system GMM estimation. Endogenous variables include *Lh* and *Rfdig*.

Appendix A Sample Countries and Groups by Income

Low-income economies (45)		**Lower-middle-income Economies (47)**		**Upper-middle-income Economies (29)**		**High-income economies (50)**	
Bangladesh	Myanmar	Albania	Jordan	**Argentina***	South Africa	Andorra	Greenland
Benin	Nepal	Algeria	Kiribati	Belize	**Turkey***	Antigua and Barbuda	**Iceland***
Burkina Faso*	Niger	Angola	Lesotho	Botswana	**Uruguay***	Aruba	**Ireland***
Burundi	**Pakistan***	**Armenia***	**Macedonia***	**Brazil***	**Venezuela***	**Australia***	**Israel***
Cambodia	Papua New Guinea	**Azerbaijan***	Maldives	**Bulgaria***		**Austria***	**Italy***
Central African Republic	Rwanda	**Belarus***	Moldova, Republic of	**Chile***		The Bahamas	**Japan***
Chad	São Tomé and Principe	Bhutan	**Morocco***	Costa Rica		Bahrain	**Korea, Republic of***
Comoros	Senegal	**Bolivia***	Namibia	**Croatia***		Barbados	Kuwait
Côte d'Ivoire	Sierra Leone	Cameroon	Nicaragua	Dominica		Belgium	Malta
Eritrea	Solomon Islands	Cape Verde	Paraguay	Gabon		Bermuda	**Netherlands***
Ethiopia	Somalia	**China***	**Peru***	Grenada		Brunei Darussalam	**New Zealand***
Gambia	Sudan	**Colombia***	Philippines	**Hungary***		**Canada***	**Norway***
Ghana	Tajikistan	**Cuba***	Sri Lanka	**Kazakhstan***		Cayman Islands	**Portugal***
Guinea	Togo	Djibouti	Suriname	**Latvia***		China, Hong Kong	Qatar
Guinea-Bissau	Uganda	Ecuador	Swaziland	Lebanon		China, Taiwan Province of	Saudi Arabia
Haiti	United Republic of Tanzania	Egypt	Syrian Arab Republic	**Lithuania***		**Cyprus***	Singapore
India*	Viet Nam	El Salvador	**Thailand***	**Malaysia***		**Czech Republic***	Slovakia
Kenya	Zambia	Fiji	Tonga	**Mauritius***		**Denmark***	**Slovenia***
Liberia	Zimbabwe	**Georgia***	**Tunisia***	**Mexico***		**Estonia***	**Spain***
Madagascar*	Yemen	Guatemala	Turkmenistan	Oman		Faeroe Islands	**Sweden***
Malawi		Guyana	**Ukraine***	**Panama***		**Finland***	**Switzerland***
Mali		Honduras	Vanuatu	**Poland***		**France***	**Trinidad and Tobago***
Mauritania		Indonesia		**Romania***		French Polynesia	United Arab Emirates
Mongolia*		Iran, Islamic Republic of		Russian Federation		**Germany***	**United Kingdom***
Mozambique		Jamaica		Seychelles		**Greece***	**United States***

Notes:

(1) 171 countries or territories were included in the original source table measuring export sophistication. From the table above, the countries or territories with * in the top right corner were ultimately retained for the purposes of the regression analysis undertaken for this paper.

(2) The income groups are divided on the basis of GNI per capita in 2006 using World Bank data.