Specialisation, Factor Endowments and Productivity: An Estimation of the Neoclassical Model

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1. Introduction

Neoclassical trade theory predicts that countries trade with each other due to differences in productivity and factor endowments[1]. These differences can act either individually or jointly to determine the pattern of actual trade. Differences in productivity are dictated by the classical Ricardian hypothesis, which states that sources of comparative advantage are either labour productivity or unit labour costs differences across countries. The neoclassical trade pattern is supplemented by the factor content approach as attributed to the Heckscher–Ohlin (H-O) theorem, which indicates as main determinants of trade, differences in relative factor endowments.

One can claim that these early developments of economic theory cannot really be applicable to a complicated global economy. These claims seem to ignore the fact that H-O and Ricardo theorems are still the most reliable devices that international trade theory provides us in order to identify the sources of specialisation and trade. Despite this, the empirical assessment of the above models in the current research agenda of international trade is rather poor. The general goal of the present thesis is to assess the empirical validity of these two theories using evidence from six European countries. The above exercise is carried out in two different stages. At the first stage, the model specified focuses only on the H-O propositions of specialisation while at the second stage, an extended model is specified allowing both H-O and Ricardian forces to determine specialisation.

The empirical validity of the Ricardian model is documented in some classical studies of Mac-Dougall (1951), Stern (1962) and Balassa (1963). However, evidence regarding the empirical validity of the Ricardian idea with recent data is rare because trade researchers tend to consider that the model relies on simplistic assumptions that cannot be met in contemporary global trade. Exceptionally, in studies by Golub and Hsieh (2000) and Choundri and Schembri (2000), the Ricardian hypothesis is revisited concluding that productivity differences still possess an important role on explaining trade flows, although these studies recognise that the model used cannot explain much of the data variation. Two points are of particular interest regarding the above studies, according to Golub and Hsieh (2000), capital and raw materials are almost perfectly mobile internationally, thus the productivity of the labour factor across countries has the strongest influence in determining

[1] Krugman (1979) and Markusen (1986) have identified as trade determinants the existence of economies of scale and differences in preferences. The former source of trade demonstrates strong empirical validity (Trefler (2002)) while the latter has been rarely analysed empirically.

comparative advantage. This finding adds support to the argument that the Ricardian model has not only a pedagogical content but it can also perform surprisingly well even with more recent data. The second point highlighted in the above studies is that there is much variation in the data, which certainly cannot be exclusively explained by the Ricardian proposition. Therefore, the explanatory power of some additional theories should be explored.

Harrigan (2001) in a review paper contradicts the core arguments of the above studies focusing mainly on two aspects. The Ricardian model is indeed simplistic regardless of the fact that capital and raw materials are internationally mobile. According to Harrigan, what matters is how capital and raw materials are allocated between alternative uses and not who owns these factors[2]. The second aspect refers to Golub and Hsieh's econometric specification in attempting to test empirically the Ricardian idea. Testing the empirical validity of a theory implies that an alternative hypothesis should be stated as a means of comparison, a key element that is absent in Golub's and Hsieh's (2000) work. A precise interpretation of the findings of the Golub's and Hsieh's (2000) study is that an increase in industry's relative productivity can lead to relatively better export performance[3]. Certainly, this finding is an interesting contribution to the empirical trade literature however, the general methodology used to obtain this result can be hardly considered as a feasible test of the Ricardian hypothesis[4].

As far as the factor endowments theory is concerned trade is generated by differences in the relative supplies of factors of production. These differences shape different relative prices and thus a need for trade. H–O trade pattern in a world of two goods, two factors indicates that a country exports goods produced intensively by its relatively abundant resource. A convenient generalisation of the H-O model in a world with n factors and m goods is described by the following equation: $AT = V - sV^W$ known as the Heckscher-Ohlin-Vanek (H-O-V) theorem. This equation states that country's vector of net exports (T) adjusted to factor intensities (A) is equal to the difference between the country's factor endowments (V) and world's factor endowments (V^w) adjusted for the country's consumption share of world endowments (s). This definition has a strong economic

[2] The above argument becomes more transparent considering the example of capital stocks and natural resources whose structural use is immobile internationally –even within countries- while their ownership can move very easily.

[3] The econometric specification of Golub and Hsieh considers as a dependent variable the relative ratio of exports between US and its trading partners in good G while the explanatory variable is a ratio of industry's labour productivity in the two countries.

[4] Harrigan emphasises that the true equilibrium effect of the Ricardian proposition is that better productivity in one sector "hurts" export performance in another sector (p.28); however, such a hypothesis is not easily testable and thus most of the evidence is silent about cross-industry productivity differences.

intuition, though its empirical implementation presents some notable difficulties. The estimation of the H-O-V prediction requires information in three different observable phenomena, namely factor input requirements as determined by matrix *A*, factor endowments and trade. While national statistics can easily give information for trade flows and factor resources, information for the requirements of factor inputs presupposes knowledge about a country's specific production function. The choice of a particular production function leads researchers to unrealistic assumptions that cause further problems to the consistency of the model.[5]

Bowen et al. (1987) provides the first assessment of the H-O-V model in a multifactor-multicountry framework. The influence of this study is of special importance in the field, though its conclusions are rather negative for the empirical performance of the theory. Their findings suggest that H-O-V provides no better prediction than a coin flip about which factor's output a country exports. As mentioned above the empirical assessment of the H-O-V theorem requires some assumptions regarding factor requirements, factor prices and consumption preferences across countries. Trefler (1995) confirms the above results about H-O-V theorem investigating further, why data have systematic deviations from the theory. Trefler (1995) explores the validity of the H-O-V considering that productivity differences are country–specific. Trefler's conclusion is that this reformulation of the original model gives a better fit with actual data. On a similar line of argument, Davis and Weinstein (2001b) and, Lai and Zhu (2006) investigate whether technological differences are industry Hicks-neutral or country Hicks-neutral. The former study shows that after relaxing some of the assumptions of the H-O-V prediction, the model performs quite well with international trade data.

Most of the studies that analyse the pattern of specialisation within a neoclassical framework use a static approach[6]. Harrigan (1995) investigates the source of comparative advantage in twenty OECD countries. His analysis is based on the argument that free trade equalises prices of goods and consequently, there is an equalisation in factor prices (FPE). According to Harrigan's argument, the presence of FPE is sufficient to lead to the assumption that a country's output is a linear function of national factor endowments. Harrigan's (1995) findings are consistent with Bowen et al. (1987) regarding the poor

[5] The H-O-V model is the benchmark model used in Leamer (1984) assuming that matrix *A* is common for all countries thus playing no role on the pattern of trade. This assumption is equivalent to consider identical technology across countries, which is itself an assumption that constitutes a crucial debate on the international trade literature.

[6] The main feature of a static approach is to modify the H-O model in order to explain sectoral output as a linear function of the aggregate factor endowments (i.e. Rybczynski effect).

explanatory power of H-O-V. Harrigan (1997) enriches the neoclassical model of specialisation using a translog approximation to the revenue function in order to estimate industry's output as a function of factor endowments and specific technological differences across countries. The empirical representation of Harrigan's (1997) model takes the form of a linear Rybczynski equation. The main message from the latter study is that both factor endowments and productivity differences are important determinants of specialisation.

The present paper is divided mainly in two sections. The first section estimates a model based on the Rybczynski effects of specialisation. The Rybczynski effect is an implication derived from a general equilibrium framework. In this model, national factor supplies are the sole determinants of specialisation taking technology as identical across countries. The Rybczynski effect relies on the rationale that an increase in a national factor supply fosters comparative advantage in the industry that uses that factor intensively. The evidence applied to test this proposition is obtained from six European countries, namely France, Germany, Greece, Italy, Spain and UK. The Rybczynski equation is widely recognised as the testable version of the H-O model and it works as well with either production or trade data. The trade version of the Rybczynski effect is applied for the case of Greek bilateral trade considering as partners the remaining countries of the sample.

The second section of the paper introduces the Ricardian technological differences as sources of specialisation. The empirical literature so far suggests that any of these theories has its own role on predicting the pattern of trade (or equivalently the pattern of specialisation) but none of them alone is sufficient to explain the entire pattern of trade. The present study seeks to contribute to the agenda by applying a joint model, initially developed by Harrigan (1997). Applying a joint model, though, has some obvious difficulties. There is a tendency in international trade studies to view H-O and Ricardian explanations as independent from each other. However, in empirical studies, this assumption needs further investigation otherwise the use of both H-O and Ricardian forces in the same model might generate misspecified results about the pattern of specialisation.

In a capital-abundant country, industries that use this factor intensively acquire a comparative advantage but a country's capital abundance is likely also to affect industries' productivity. The reason why the H-O propositions are likely to bias the contribution of Ricardian forces to the patterns of specialisation is due to the failure of factor price equalisation (FPE). If factor rewards are not equalised across countries then industries find it more beneficial to substitute the relatively expensive factor with the cheaper one. Under standard assumptions, it is widely accepted that differences in relative factor rewards are driven by differences in relative factor abundance. From these considerations, the following link is emerged: capital abundant countries are biased towards capital services in all industries. The implication of such a process implies that capital-abundant countries are likely to maintain higher relative productivity in all industries. This hypothesis is not arbitrary as one may assume, since it is derived from the key assumption of the endogenous growth theory that technical progress and hence productivity growth is generated via investment in capital assets.

The above issue is carefully addressed by examining to what extent country's factor endowments drive factor mixes at the industry level. Once the above problem is tackled, the next step is to estimate a joint model quantifying the contribution of each force to the pattern of specialisation. The paper is organised as follows, section 2 presents an analytical framework of the sources of specialisation. This framework builds upon a translog revenue function, which is simplified in steps leading to an estimatable Rybczynski equation, which is the main empirical vehicle throughout the chapter. Section 3 discusses briefly some data sources and relevant issues. Section.4 estimates the Rybczynski regressions for both the pattern of specialisation and trade. Section 5 is devoted to estimate various specifications of a joint model including both H-O and Ricardian factors. This section also presents the method used to construct the productivity index as well as the test conducted to identify whether the H-O and the Ricardian model are correlated with each other. Section 6 concludes drawing some policy implications derived from the analysis carried out in the paper.

2. Sources of Specialisation

A convenient way to demonstrate the sources of specialisation within a neoclassical framework is to follow the approach of the revenue function that Dixit and Norman (p.31 (1980)) initially suggested and Harrigan (1997) empirically assesses. The key characteristic of this analysis is that national income can be expressed as a function of factor endowments and final good prices.

$$Y = r(P, V) \tag{1}$$

P is a vector of prices and V is a vector of national factor endowments. The revenue function is homogeneous of degree one in P and V. Under the assumptions that the revenue function is continuous and twice differentiable, the gradient of (1) with respect to prices gives the amount of output that maximises the national income. Assuming that technology is identical across countries then specialisation across countries is determined exclusively by the differences in P and V. However, a large number of studies reveal that there are significant productivity differences across countries (Dollar and Wolff (1993), Harrigan (1999), O'Mahony and Van Aark (2003)). To include the technological factor in the model, it is first required to make some plausible assumptions for how technology differs across countries.

Trefler (1995) models technological differences as being sector neutral and country specific. This formulation, as discussed earlier, allows adjusting factor endowments in productivity units in the HOV equation but it does not explain how technological differences affect comparative advantage. Instead, the present framework follows Harrigan's (1997) methodology and formulates technology differences as industry specific and country neutral. Consider the technological parameter $q_{i,c,t}$ for industry i in country c at year t. If this parameter is Hicks-neutral then with the same amount of inputs, industry i in country c at year t is q times more productive than a reference country. The attractive feature of this productivity formulation is that technological differences can be measured applying a standard total factor productivity (TFP) index.

The technological parameter q can be introduced directly into (1) thus the revenue function is re-expressed as:

$$Y = r(\Theta P, V) \qquad (2)^{7}$$

where $\Theta = dia\{q_i,...,q_I\}$ is a diagonal matrix that includes the Hicks-neutral technological parameters of industries $i….I$. In industry i, the differentiation of (2) with respect to q_i establishes the elasticity of industry's output after a change in technical efficiency:

$$\tilde{x}(q\, p_i, V) = \frac{\partial r(q_i p_i, V)}{\partial q_i} \qquad (3)$$

The next step is to derive an empirical expression for the revenue function $r(\Theta P, V)$. Following Woodland (1982), Kohli (1991) and Harrigan (1997), the revenue function can be adequately approximated by using a second order translog function. The specific form of the revenue function becomes:

[7] If one follows Trefler's (1995) way in modelling technological differences, then the assumption of homogeneity implies that the revenue function is written as: $Y = \Theta r(P, V)$. This formulation suggests that a positive technological shock increases output in all industries thus affecting country's absolute rather than comparative advantage.

$$\ln r(q\,p,V) = b_{00} + \sum_i b_{1i} \ln q_i p_i + \sum_j b_{1j} \ln V_j + \sum_i \sum_j b_{i,j} \ln q_i p_i \ln V_j +$$
$$\frac{1}{2}\sum_i \sum_k b_{i,k} \ln q_i p_i \ln q_k p_k + \frac{1}{2}\sum_j \sum_m b_{j,m} \ln V_j \ln V_m \qquad (4)$$

where the summations in i and k refer to industries and run from 1 to I and the summations j and m refer to factor endowments and run from j to J. By assuming symmetry of cross effects then it is implied that: $b_{i,k} = b_{k,i}$ and $b_{j,m} = b_{m,j}$. Similarly, the linear homogeneity restriction in the revenue function yields[8]:

$$\sum_i b_{1i} = 1 \quad \sum_j b_{1j} = 1 \quad \sum_j b_{i,j} = 0 \quad \sum_i b_{i\,k} = 0 \quad \sum_m b_{j,m} = 0$$

Differentiating (4) with respect to p_i (after adding country subscripts) and applying the homogeneity restriction $\sum_j b_{i,j} = 0$ and $\sum_i b_{i,k} = 0$, the following equation emerges:

$$s_{i,c} = b_{0\,i,c} + \sum_i b_{1i} \ln q_i p_i + \sum_j b_{1j} \ln V_j \quad \text{or}$$
$$s_{i,c} = b_{0\,i,c} + \sum_i b_{1i} \ln q_{i,c} + \sum_i b'_{1i} p_{i,c} + \sum_j b_{1j} \ln V_{j,c} \qquad (5)$$

Equation (5)[9] states that industry i's output share (s) to country's GDP is a function of technology, prices of final goods and factor endowments. Supposing that trade equalises prices of final goods across countries (i.e. free trade)[10] and by adding a time subscript in (5) then it yields:

$$s_{i,c,t} = b_{0\,i,c} + r_{i,t} + \sum_i b_{1i} \ln q_{i,c,t} + \sum_j b_{1j} \ln V_{j,c,t} \ ,$$
$$\text{where } r_{it} = \sum_i b'_{1i} p_{i,t} \qquad (6)$$

If technology is identical across industries within a country (i.e. $\ln q_{i,c,t} = \ln q_{c,t}$) then the second summation in equation (6) can be substituted by a set of country and year fixed effects. In this case, the pattern of specialisation depends exclusively on factor supplies:

[8] Without applying the linear homogeneity restriction, the translog revenue function implies that price changes or technological changes in one industry have general equilibrium effects on other industries. However, no particular attention is given to this cross- industry effect of (4) when the estimatable equation is formulated.
[9] Since equation (5) is derived from a translog approximation then it holds for all countries and time periods.
[10] This issue becomes more complicated if one assumes that there are many no-traded goods in the economy and thus prices are not equalised via trade. There is no information for prices in the non-traded sector and thus it is quite difficult to incorporate these elements into the analysis. An alternative view is to consider that these effects are country specific thus, their impact can be controlled using country dummies.

$$s_{i,c,t} = b_{0\,j,c} + r_{i,t} + l_{c,t} + \sum_j b_{1j} \ln V_{j,c,t} \qquad (6)'$$

Equations (6) and (6)'are the conceptual equations upon which the empirical analysis of the forthcoming sections is developed. Equation (6) represents an extended version of the Rybczynski effect allowing for an industry specific technology. Equation (6)' represents the strict version of the Rybczynski effect, which states that at constant prices, an increase in the supply of a factor will lead to an increase in the industry's output that uses intensively that factor and a reduction in the output of the other industry.

3. Data Sources

The data used in the present analysis refer both to the industry and country level. The industry level data concentrate on output shares, trade flows, and various measures of industrial performance. The study includes 6 countries, France, Germany, Greece, Italy, Spain and UK by covering activities of 13 manufacturing industries. Output share is measured as industry's share to country's value added and data are taken from OECD-Structural Analysis (STAN) (ISIC Rev.3) for the period 1987-2003. Data on Greek trade flows are obtained from the OECD bilateral trade database and refer to export-import flows of these manufacturing industries for the period 1988-2004. Other data on industrial performance are taken from OECD-STAN providing (see Appendices 1 and 2 for a summary of data sources) information about value added, employees, labour compensation and gross fixed capital formation[11]. The industry level data obtained from STAN are utilised to construct *TFP* indices.

The set of economy-wide factor supplies includes land, energy, fixed capital and three types of labour. These data are taken from World Bank Development Indicators. Land is measured in hectares of arable land, energy factor includes production of energy sources converted into oil equivalent, and capital formation includes both the level of inventories and various purchases of fixed assets (i.e. land improvements, plant, machinery, construction and various equipments). Labour data are obtained from UNESCO, which classifies workers in three different groups: (1) labour force with primary education, (2) labour force with secondary education and (3) labour force with tertiary education. In the empirical estimation, workers with primary and secondary education are aggregated to a single group referred to as less skilled labour and the third group represents skilled labour.

[11] For the industry level variables, STAN reports deflators for value added and capital; these deflators are applied to convert nominal values to real ones.

Further information about various problems encountered in the construction of the variables is presented in the Appendix 1. Table (1) displays average values of relative factor endowments for the six countries. All factor supplies are expressed relative to aggregate labour. The table verifies some common beliefs regarding factor abundance in Europe but also points out some new interesting remarks. France is the most capital abundant country of the sample and probably the most capital abundant country in Europe whilst, as expected, Greece has the lowest capital labour ratio. The pattern is slightly different in the relative abundance of skilled labour in which Spain and Greece are the leading countries. The scarcest country in skilled labour is Germany with a 5.4% percent of the total labour force to possess a degree of tertiary education; a similar number is documented for UK. More distinguishable are the differences regarding abundance of arable land. Spain, France and Greece are those countries with the highest ratio of arable land per worker while the lowest ratio exists in UK.

Table 1 Relative Factor Endowments (1987-2003)

Country	*K/L*	*SL/L*	*A/L*	*E/L*
France	145,451	0.074	0.718	0.005
Germany	38,579	0.054	0.300	0.004
Greece	18,312	0.073	0.630	0.002
Italy	54,668	0.070	0.364	0.001
Spain	29,597	0.088	0.859	0.002
UK	28,567	0.057	0.213	0.008

Notes:
(*K/L*) is capital stock per worker; (*SL/L*) is the share of workers with at least a degree from tertiary education over the total number of workers; (*A/L*) is arable land per worker; (*E/L*) is energy per worker. Ratios refer to average values over the whole period. Capital is a stock measure constructed via a standard perpetual method and expressed in US dollars. Capital stock series starts from 1988. More details about the definition of the variables can be found in the text.

Table (2) reports the percentage share of total manufacturing value added in GDP and the share of each industry's value added in total manufacturing for all six countries in the sample. A common feature for all countries is that the share of total manufacturing in GDP declines in the period under study. The rate of decrease varies substantially across countries, the most rapid decrease is observed in UK, which is 36% percent between 1988 and 2002. Except for the share of the textiles industry that declines substantially for all countries, it is difficult to draw a clear pattern regarding the movements of value added share in total manufacturing. Greece experiences the largest decrease in the share of this industry, which is 32.4% in 1988 and decreases to 15.7 in 2002, indicating a declining rate of 51%.

Table 2 Value Added Share of Manufacturing Industries to GDP

Industry	Time Period	France	Germany	Greece	Italy	Spain	UK
Food products	Average	14.25	8.91	21.00	10.37	16.21	13.81
	1988	13.30	7.90	16.10	9.70	16.90	13.00
	2002	14.90	9.30	21.70	10.90	14.40	14.20
Textiles	Average	5.60	3.09	22.97	14.38	8.36	5.38
	1988	7.20	4.40	32.40	15.60	10.10	6.80
	2002	4.30	2.10	15.70	12.70	6.80	3.80
Wood and product	Average	1.70	1.89	2.91	2.72	2.55	1.53
	1988	1.60	1.50	2.70	2.60	2.60	1.70
	2002	1.60	1.70	2.20	2.90	2.40	1.70
Pulp, paper,	Average	8.47	7.55	6.74	6.56	8.15	12.53
	1988	8.20	7.00	5.50	6.10	7.40	11.30
	2002	8.30	7.50	8.30	7.10	9.10	13.80
Coke and refined Petroleum	Average	2.87	0.84	4.48	1.77	2.80	2.03
	1988	2.20	0.80	2.50	1.20	3.20	2.30
	2002	3.50	1.10	7.60	0.90	2.90	1.70
Chemicals	Average	10.19	10.05	5.78	7.98	8.89	10.54
	1988	9.30	11.50	5.20	8.30	9.00	10.80
	2002	11.10	10.10	5.60	8.30	9.20	10.90
Rubber and plastics	Average	4.56	4.76	2.63	4.04	4.44	4.96
	1988	4.80	4.30	2.30	3.60	3.80	4.20
	2002	4.40	5.00	2.80	4.20	5.00	5.30
Other non-metallic	Average	4.91	4.01	6.56	6.30	7.65	3.53
	1988	5.10	3.80	5.80	6.10	7.50	4.10
	2002	4.70	3.30	8.30	7.00	8.10	3.60
Basic metals	Average	13.29	13.06	9.46	13.89	12.05	11.09
	1988	13.30	13.00	12.20	14.00	12.20	12.10
	2002	12.90	13.00	9.10	13.30	13.50	10.10
Machinery	Average	7.77	14.59	2.97	11.57	6.33	8.41
	1988	8.60	14.20	2.40	11.20	5.90	8.40
	2002	6.70	15.30	3.30	12.40	7.20	8.20
Electrical	Average	11.67	14.70	3.29	9.48	7.41	12.38
	1988	12.40	16.30	2.70	9.90	7.50	12.50
	2002	10.40	13.50	3.80	9.00	6.50	11.40
Transport	Average	10.76	13.53	4.53	6.08	10.73	10.24
	1988	9.60	12.50	3.50	6.70	9.80	9.80
	2002	13.50	15.40	5.80	6.30	10.40	10.80
Other Manufacturing	Average	4.09	2.99	6.69	4.85	4.37	3.59
	1988	4.40	3.00	6.50	4.90	4.00	2.80
	2002	3.70	2.70	5.90	5.00	4.50	4.50
Share of the Total Manufacturing Sector to GDP	Average	18.84	24.36	13.39	21.59	18.87	19.72
	1988	21.10	29.80	16.60	24.70	22.30	23.70
	2002	17.80	22.30	11.50	19.50	16.70	15.20

Notes:
Industry names follow ISIC (Rev 3) classification. Numbers represent percentage points.

The next section estimates a model of trade specialisation using bilateral trade data for the case of Greece. The study focuses on trade flows only with the remaining five countries of the sample (France, Germany, Italy, Spain and UK). The selection of these countries is not random as flows from (and to) these countries account on average for the 75% and 84% of total imports and exports from (and to) EU-15. Greek trade with these countries is also large compared to the total trade, particularly imports and exports from (and to) these countries cover the 51% and 47% of Greek imports and exports from (and to) the rest of the world. Appendix 3 presents average trade shares with each of these partners.

4. Specialisation and Factor Endowments

This section presents an estimatable version of equation (6)', which highlights the Rybczynski effects of specialisation. Despite the simplicity of the Rybczynski equation, this model remains among the most popular devices used to identify the structure of production and the pattern of trade. Two potential problems are encountered regarding the empirical representation of (6)'. The first is that factor endowments are not adjusted in productivity units and thus one can claim that might produce misspecified results regarding the contribution of H-O forces to determining specialisation. In the current framework, this problem is easily overcome, because productivity differences are assumed to be industry specific and as such, they are modelled separately[12]. The second problem is that the original Rybczynski specification does not express factor supplies in a relative manner, as it is required from the H-O theory. We address this problem by expressing all factor supplies relative to labour in equations (6) and (6)'.[13]

Summarising the above discussion, the estimatable version of (6)' is as follows:

$$s_{i,c,t} = b_{0i,c} + b_1 \log\left(\frac{K}{L}\right)_{c,t} + b_2 \log\left(\frac{SL}{L}\right)_{c,t} + b_3 \log\left(\frac{A}{L}\right)_{c,t} + b_4 \log\left(\frac{E}{L}\right)_{c,t} + u_{i,c,t} \qquad (7)$$

The dependent variable is industry *i*'s output share in country *c*'s GDP at year t. the right hand side consists of four national-wide factor endowments of capital (*K*), skilled labour (*SL*), arable land (*A*) and energy (*E*) expressed relative to total labour (*L*). This modified version of the Rybczynski theorem is also met in Fitzgerald and Hallak (2004)-though, without the energy endowment-and it carries many similarities with the specification of

[12] This task is carried out in section (5), which uses industry-specific productivity indices as a proxy for the technology variable $q_{i,c,t}$.

[13] Fitzgerald and Hallak (2004) re-scale the Rybczynski equation to nest the obvious alternative hypothesis that industry's output level depends on country's size. Given that the present framework is based on a log-linear translog approximation to the revenue function this transformations is not necessary.

Harrigan (1995), Redding (2002) and Reeve (2006), offering a useful basis for comparing our results.

Equation (7) tests the Rybczynski effects with production data implying that industry's share output is a function of relative factor endowments. To provide a more direct test of the Rybczynski effects with reference to trade, equation (6)' is also tested for the case of Greek bilateral trade. To implement this task, an additional assumption is necessary to ensure that demand conditions between trading partners are identical, that is, residents in countries involved in trade exhibit common preferences. On this base, industry's net output[14] is equal to industry's net exports. This specification is tested with particular interest in Greece's bilateral trade with France, Germany, Italy, Spain and UK. The trade specification is written as:

$$\log\left(\frac{X}{M}\right)_{i,h,t} = g_{0i,c} + g_1 \sum_{j=4} \log\left(\frac{V_{j,h,t}}{V_{j,f,t}}\right) + u_{i,h,t} \qquad (8)$$

The left-hand side of equation of (8) is an exports (X)-imports (M) ratio in industry i expressed from the standpoint of Greece (denoted with the subscript h). The right-hand side of (8) includes the same sum of relative factor endowments as in (7) but the relative factor endowments in country h are now expressed relative to the factor endowment of the trading partner f. Intuitively this specification suggests that the net exports in a capital-intensive industry are increased as the capital-labour ratio of country h (i.e. Greece) increases relative to the capital-labour ratio of the trading partner.

Equation (7) is estimated after pooling data across countries and years. Table (3) reports results for each industry applying a Seemingly Unrelated Regression (SUR). Strong inference can be made for capital and energy intensity. The ratio of capital–labour (*K/L*) is positive in ten out of thirteen industries and in eight of them is statistically significant at conventional levels; such a result is consistent with the key stylised facts revealed in other studies supporting evidence from other studies regarding the positive role of capital on the pattern of specialisation (Harrigan (1995)). The energy-labour (*E/L*) ratio appears with a positive sign in ten out of the thirteen industries and it is frequently statistically significant (i.e. in six industries). No particular conclusion can be drawn for the remaining two factor endowments, namely skilled labour and arable land. Their impact on industries' output share is not clearly specified and most crucially, coefficients of these factors are statistically insignificant in most of the cases.

[14] Industry's net output is defined as production minus domestic consumption.

Table 3 Output Shares and Factor Endowments

Industry	*K/L*	*SL/L*	*A/L*	*E/L*	N	R-squared
Food Products	0.503**	-0.118	-0.624	0.723***	88	0.95
	(2.21)	(-0.63)	(-1.30)	(2.75)		
Textiles	0.982***	-0.22	-0.486	0.702**	88	0.93
	(3.51)	(0.95)	(0.83)	(2.17)		
Wood	-0.006	0.749***	0.329	-0.337	88	0.87
	(0.031)	(4.62)	(0.80)	(1.49)		
Pulp and Paper	0.783***	-0.181	-0.702	0.587*	88	0.92
	(2.84)	(0.79)	(1.21)	(1.84)		
Coke	0.772	0.386	-2.325**	0.682	88	0.91
	(1.43)	(0.86)	(2.05)	(1.09)		
Chemicals	1.229***	0.502	-1.061	1.092**	88	0.94
	(2.79)	(1.38)	(1.14)	(2.15)		
Rubber	0.750**	0.29	-0.0491	0.434	88	0.94
	(2.20)	(1.03)	(0.068)	(1.10)		
Other non-metallic	0.541***	-0.219*	0.144	0.688***	88	0.84
	(3.50)	(1.72)	(0.44)	(3.86)		
Basic Metals	-0.550***	0.187*	1.006***	-0.443***	88	0.76
	(4.09)	(1.68)	(3.55)	(2.85)		
Machinery	0.345	-0.167	0.989*	0.0525	88	0.95
	(1.27)	(0.74)	(1.73)	(0.17)		
Electrical	0.767***	-0.156	0.596	0.544**	88	0.85
	(3.36)	(0.82)	(1.24)	(2.06)		
Transport	0.280*	0.197	-0.728**	0.193	88	0.96
	(1.83)	(1.55)	(2.25)	(1.09)		
Manufacturing	-1.351***	1.599***	0.652	-1.972***	88	0.66
	(2.59)	(3.71)	(0.60)	(3.28)		

Notes:
The estimation method used in the table is Seemingly Unrelated Regression (SUR). Absolute t-values are shown in parentheses. The asterisks correspondence is *significance at 10%;**significance at5%;***significance at 1%. All regressions include year dummies, (not shown).

Results from the Rybczynski regression with trade data (i.e. equation (8)) are reported in table (4). The same procedure is followed, data are pooled across trading pairs and years and results reported for each industry using the SUR estimation. There is an expected radical change in the sign of capital abundance, which confirms the different pattern of production structure between Greece and its trading partners. The coefficient of the capital-labour ratio is consistently negative and frequently statistically significant. On the contrary, the estimated coefficient of arable land appears positive and statistically significant in five industries. For skilled labour and energy abundance, it is quite difficult to sketch a conclusive pattern since the associated estimated coefficients vary across industries and frequently appeared statistically insignificant. These results have a clear economic interpretation that an increase in capital abundance is a negative determinant of Greek trade flows. However, equations (7) and (8) are misspecified if one seeks to interpret them in line with the propositions of the H-O theory.

Table 4 Factor Endowments and Greek Bilateral Trade

Industry	R.*K/L*	R.*SL/L*	R.*A/L*	R.*E/L*	N	R-squared
Food Products	0.213	-2.545**	-3.586***	3.013***	75	0.79
	(0.31)	(2.34)	(2.79)	(3.54)		
Textiles	-1.691***	0.569	-2.951***	0.139	75	0.95
	(4.54)	(0.95)	(4.17)	(0.30)		
Wood	-0.242	-4.225	-5.799*	3.758*	75	0.68
	(0.14)	(1.48)	(1.71)	(1.68)		
Pulp and Paper	0.801	2.231	6.972***	-0.763	75	0.59
	(0.78)	(1.34)	(3.55)	(0.59)		
Coke	8.878***	-2.478	11.36**	2.679	75	0.54
	(2.97)	(0.52)	(2.00)	(0.71)		
Chemicals	-1.939***	-0.717	-0.0698	0.937	75	0.69
	(3.27)	(0.75)	(0.062)	(1.26)		
Rubber	-1.636***	0.777	2.422***	0.0738	75	0.88
	(3.53)	(1.04)	(2.74)	(0.13)		
Other non-metallic	-1.892***	2.935***	5.673***	-2.536***	75	0.78
	(2.72)	(2.62)	(4.28)	(2.90)		
Basic Metals	-1.151	-1.12	2.683*	-0.482	75	0.58
	(1.52)	(0.92)	(1.87)	(0.51)		
Machinery	-1.208**	2.114**	4.598***	-1.599**	75	0.86
	(2.10)	(2.29)	(4.21)	(2.21)		
Electrical	0.953	-1.07	-1.411	0.0361	75	0.67
	(1.26)	(0.88)	(0.98)	(0.038)		
Transport Equipment	2.224	-1.125	-3.532	4.045**	75	0.59
	(1.57)	(0.49)	(1.31)	(2.28)		
Manufacturing	-1.954***	-2.197***	-0.818	1.483**	75	0.87
	(4.00)	(2.79)	(0.88)	(2.41)		

Notes:
Table presents estimates from equation (8), right-hand side variables are relative (R) factor endowments of Greece vis-à-vis that of the importing country. The estimation method used in the table is Seemingly unrelated Regression (SUR). Absolute t-values are shown in parentheses. The asterisks correspondence is *significance at 10%;** significance at 5%;***significance at 1%. All regressions include year dummies, (not shown).

To interpret the above results more tightly with regard to the H-O predictions some insightful information is required regarding the intensity of the above factors at the industry level. It should be noted that the validity of H-O theory in the literature is tested with the use of sign and rank tests that they are in principal non-parametric techniques (James and Elmslie (1996)). These tests are quite restrictive since they provide clear trade predictions only in the case of a two good-two factor model. If the analysis involves a higher dimensionality with more factors and industries, the H-O predictions are not straightforward. To draw some inference for the validity of the H-O theory it is necessary to find the correspondence between country's factor endowments and the associated factor intensity at the industry level. Table (5) reports mean values of capital and energy intensity ratios at the industry level over all countries and years. Industries' capital and energy intensities are taken from the OECD-STAN and GGDC-KLEMS databases, respectively. Panel A shows capital-labour ratios for the whole sample, for Greece and for Greece's trading partners, respectively. Panel B shows energy intensity ratios for the whole sample only[15]. Both panels rank industries in accordance to their factor intensity.

The interpretation is initially focused on industries of table (3) that have a negative and statistically significant coefficient of capital abundance, namely basic metals and other manufacturing. These estimated coefficients of factor endowment match quite well the actual capital intensity of these industries since both of them are quite low in the associated ranking (Panel A). Industries with a negative estimated and statistically significant coefficient of energy-labour are again basic metals and other manufacturing. The latter is placed last in the corresponding ranking while the former is in the middle. Considering industries with a positive estimated coefficient of energy–labour such as chemicals and other non-metallic their associated ranking in table (5) is high verifying that there is a clear relationship between the estimated impact of national factor endowments and the actual factor intensity.

Comparing capital intensity of Greece with its trading partners in panel A, it is clearly indicated that Greece uses this factor less intensively in all industries. Based on this, the negative estimates of capital-labour ratios in table (4) are perfectly consistent with the propositions of the H-O theory. Unfortunately, there is no information about actual intensity of arable land at the industry level and thus it is impossible to check whether the positive estimated coefficients are in harmony with the actual intensity.

Overall, the present analysis- after using both production and Greek trade data - suggests that the mechanisms of H-O theory are at work. Building the empirical analysis upon the Rybczynski general equilibrium effect, remarkable evidence comes on surface both regarding the sources of specialisation and the validation of the H-O model. The main intuitive idea behind these findings is that an increase in the abundance of a factor reinforces comparative advantage in the industry that uses intensively that factor. Analysing the pattern of specialisation within a Rybczynski framework seems to perform equally well in a bilateral perspective at least as far as the case of Greek trade is concerned. The robust

[15] Data for energy intensity are not available for Greece; hence only data for capital intensity are reported.

estimates produced for the Greek trade with five European partners imply a more vital implication regarding the power of H-O model to explain trade flows. That is, the larger are the differences in factor abundance between the trading partners, the better is the performance of H-O. Recent studies of Debaere (2003) and Lai and Zhu (2006) also confirm this intuitive result.

Table 5 Factor Intensity by Industry- Average Values for the Period 1988-2002

Panel A				Panel B	
Industry[A]	Capital Intensity[B]- **Entire Sample**	Capital Intensity- **Greece**	Capital Intensity- **Trading Partners**	**Industry**	Energy Intensity[C] **Entire Sample**
Coke	195.29	14.99	231.35	Coke	298.38
Electrical	140.12	6.53	166.84	Chemicals	31.46
Transport equipment	124.88	2.53	150.36	Rubber and plastics	26.88
Chemicals	102.76	12.16	120.88	Other non-metallic	14.54
Machinery	74.18	0.39	88.94	Electrical	9.24
Rubber and plastics	74.12	3.07	88.33	Basic metals	5.08
Pulp and paper	72.89	2.06	87.05	Wood products	4.37
Other non-metallic	69.33	3.52	82.49	Machinery	4.04
Basic metals	62.36	3.41	74.15	Transport equipment	3.68
Food products,	54.89	5.02	64.87	Food products,	3.40
Wood products	41.33	3.61	50.76	Pulp and paper	2.80
Other-Manufacturing	37.91	11.42	43.21	Textiles,	2.03
Textiles	25.42	5.80	29.35	Other Manufacturing	1.79

Notes:

A. Industries are in descending order according to their factor intensity
B. Capital intensity is measured as the ratio of capital stock per employee. Capital stock is constructed via a perpetual method, (see next section form more details) from data on fixed capital assets reported by OECD-STAN
C. Data for intermediate energy inputs are taken from GGDC-KLEMS and energy intensity is the ratio of energy inputs per employee

5 Technology Differences and Specialisation

The Rybczynski specification (6)'represents a general equilibrium linkage between changes in the mixes of endowments and changes in the mixes of output. This model is silent about the equilibrium effect of technology on changes in the pattern of specialisation[16]. Nevertheless, a scenario that systematically excludes productivity as a

[16] Given that productivity index represents a technical efficiency parameter, the terms "technology" and "productivity" have actually the same meaning.

potential source of specialisation should be viewed as incomplete if we take into account that a marked outcome from international productivity studies is that productivity differences are large. This outcome implies that productivity differences may have a strong impact on specialisation and thus their role should be carefully addressed.[17] Returning to the original specification (6), a technological parameter *?* is specified to reflect the role of technology. A key issue is how these productivity disparities are modelled; Trefler (1995, 2002) adjusts the factors of production in productivity units but in a fashion that technology matters for the absolute rather than the comparative advantage of countries. The present study follows Harrigan's methodology (1997) and assumes that *?* is industry specific and country neutral.

By allowing the present framework to include productivity as a source of specialisation, the emerged model is a unified model that includes both theoretical devices (Heckscher-Ohlin and Ricardo) of international trade. The initial formulation of these workhorse models of international trade theory is simplified, which implies that a consistent estimation of a joint model presupposes that some key issues are clarified before proceeding to the empirical estimation. A crucial attribute of the Ricardian model is that productivity is specified as exogenously determined. Taking technology as exogenous is convenient for the initial exposition of the model; however, when the model involves the estimation of a joint specification, the a-priori assumption of exogenous technology is at least ambiguous. In fact, it could be argued that these two branches are likely to be interrelated. As pointed out in the introduction, the theory of endogenous growth suggests that technological improvements are strongly associated with national factor endowments and more specifically with the accumulation of physical and human capital. According to this view, a capital abundant country is likely to be more productive in all industries than a less-capital abundant country simply because it has the opportunity to substitute labour inputs with more advanced capital techniques. Similarly, if human capital affects productivity performance positively then a country relatively well endowed with skilled workers is able to experience superior productivity in all industries. If the above mechanisms are at work, then national factor endowments are correlated with sectoral productivity thus the estimation of a unified model will not provide clear indications for the

[17] See for reference, Dollar and Wolff (1993), McKinsey (1993), Harrigan (1999) and Golub and Hsieh (2000).

contribution of H-O and Ricardian models to the pattern of specialisation[18]. This section works through an empirical test to detect whether national factor endowments have feedback effects on industry's productivity and then estimates a joint model. Before proceeding with the above tasks, it is necessary to describe the construction of *TFP* and clarify key issues related to the measurement of the variables.

5.1 *TFP* Comparisons

The methodology used to construct *TFP* is very similar to approaches applied by Van Aark (1993) and Pilat, and Harrigan (1999)), which build on the theory of index numbers by Caves et al. (1982). We assume that output is a value added function produced by the use of two inputs, labour and capital. For each industry i of country c at year t (industry and time subscripts are omitted hereafter for simplicity) the production function is written as:

$$y_c = f(l_c, k_c)$$

More specifically, we consider a production function with constant returns to scale:

$$y_c = A_c l_c^{a} k_c^{1-a}$$

Parameter A embodies the concept of total factor productivity in a Solow residual fashion. In a similar way, the production function of the reference country is determined as follows:

$$\bar{y} = \bar{A}\bar{l}^{a}\bar{k}^{1-a}$$

The logarithmic expression of the relative *TFP* is given as:

$$\log TFP_c = (\log y_c - \log \bar{y}) + a(\log l_c - \log \bar{l}) + (1-a)(\log k_c - \log \bar{k}) \qquad (9)$$

where $\log \bar{y}$, $\log \bar{l}$ and $\log \bar{k}$ are average values across observations in the sample. In the calculation of the multilateral *TFP* index the labour share is measured by $a = (x_h + \bar{x})/2$, x_c

[18] Assume a capital abundant country with an identical industry in which TFP is the key driving factor for changes in industry's output share to GDP. In this case, the national relative capital-labour ratio is of minor importance. Paying no attention to the possible scenario that factor abundance drives TFP at the disaggregate industry level; economists will tend to believe that Ricardian forces is what really matters for industry's comparative advantage. However, this is a misleading argument if the true effect is that the source of high productivity performance is driven by the fact that the mix of industry's inputs is biased towards capital due to country's capital abundance. Morrow (2006) makes the above argument even more plain illustrating an example with US and China. US has the largest world share in the supply of aircrafts while China maintains the highest world share as a textiles supplier. It is reasonable to assume that the most productive industry in US is the aircraft industry while textiles is the most productive industry in China. The crucial question emerged is which are the real sources of productivity superiority in each of these industries? Following the common belief that US and China are well endowed in skilled and unskilled labour respectively, one can argue that the national factor supplies drives productivity superiority in these industries.

is the labour share of country c. Imposing a constant returns to scale assumption, then the capital share is equal to one minus the labour share. Initially, the labour share is computed as the ratio of labour compensation to value added. In many cases, this ratio is quite noisy exceeding unity. To control for these imperfections, an approach proposed by Harrigan (1999) is followed by replacing labour share values greater than one with fitted values from the following OLS regression:

$$\log\left(\frac{w}{va}\right)_{i,c,t} = b_0 + b_1 \log\left(\frac{l}{k}\right)_{i,c,t} + e_{i,c,t}$$

This regression is estimated for each industry, including a set of country and year dummies. Equation (9) is a special case of Harrigan's (1999) functional *TFP* formula and it is directly derived from a translog production function. This index is transitive,[19] making no difference which country is used as a means of comparison (i.e. in the present study, the reference point is an average over all observations in the sample).

The measurement of labour input in equation (9) is in physical units multiplying the number of employees by the number of average hours worked. However, value added, labour compensation and capital should be measured in a common currency value. The STAN database reports values for EMU countries in Euros (i.e. this excludes UK). Data are converted into a common currency, namely US Dollars, by using the purchasing power parity (PPP) exchange rate reported by the World Bank Indicators - International Comparison Project (ICP). Once the variables are converted into a common currency, the next step is to make the data comparable across years. To do so, value added, labour compensation and capital in (9) are expressed in 1995 constant prices using the associated variable deflators reported in the STAN database.

Admittedly, there are limitations regarding the conversion method used since the World Bank PPP-exchange rate is based on GDP prices, which are common across all sectors of the economy. This can be potentially problematic as output prices are likely to differ across sectors. GGDC (ICOP) develops an interesting methodology for the construction of PPP-exchange rates appropriate for international productivity comparisons at a disaggregate industry level[20]. Unfortunately, this data set is only available for 1997.

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[19] The property of transitivity implies that for any three countries c, c', c'', the following equality is satisfied: $TFP_{cc'} = TFP_{c'c''} TFP_{cc'}$.

[20] Details regarding the construction of disaggregate PPP exchange rates can be found in van Ark et al.(2002).

Hence, we have to cope with the aggregate PPP-exchange rate provided by the World Bank indicators.

The capital input used in (9) is a stock measure derived by a perpetual method[21]. Gross capital flows from STAN include investments in fixed and financial assets. The accumulation of capital stock is derived from the following equation:

$$K_t = K_0 + (1-d)\,investment_{t-1}$$

where d is a depreciation rate of capital assets, currently assumed to be at 10% and K_0 is the level of initial capital stock[22]. The initial capital stock is obtained by the ratio: $K_{0,i} = \frac{investment_{0,i}}{g_i + d}$, where *investment* is capital purchases in industry i on the first year available in the sample (i.e. 1987) and g is the average growth rate of capital purchases over the whole period. Productivity is a strictly procyclical variable and thus dependent on business cycle movements. OECD (Main Economic Indicators) reports data on a quarterly basis for the degree of capacity utilisation in the aggregate manufacturing sector. The cyclicality of *TFP* is captured by capital stock with the share of capacity utilisation. This indicates that the effect of the business cycle matters only for cross-country comparisons and not for comparisons across industries in the same country[23].

Appendix 4 displays average *TFP* values from (9)[24] over the period 1987-2002. The table illustrates Germany's productivity superiority in almost all manufacturing industries followed by France, which in some cases exceeds Germany's *TFP* level. UK *TFP* approaches the level of Germany only in the food industry while in the remaining industries the *TFP* gap between the two countries remains quite large. A similar pattern applies for Italy and Spain; the relative *TFP* level is very close to 100 in food industry and higher than this in the industry of coke and refined petroleum, signifying Italy's and Spain's productivity advantage. Finally, Greece has a clear productivity disadvantage in all

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[21] STAN already reports data on capital stock by aggregating past and current capital assets; however, an appropriate capital stock measure should be adjusted for an efficiency depreciation of the capital assets. Therefore, the inventory method followed, adjusted for efficiency losses occurred over time, representing a more accurate measure of capital stock.

[22] No consistent data exist for fixed capital formation in the Greek Industry of Transport Equipment and since the Greek industry is the numeraire country of the TFP comparisons, this industry is dropped for the remaining analysis.

[23] Given that the current study focuses on cross-country TFP comparisons at the industry level, the fact that the utilisation index is aggregate does not prevent from measuring the effect of business cycle across years. However, movements over the business cycle are likely to have different cross-industry effects within the same country since the effect of utilisation is strongly determined by industry's individual capital-labour ratio.

[24] To make figures easily readable in table (B3.4), we take the exponential values of the TFP index in equation (3.9).

industries with the exception of the coke industry in which Greece is 60% as productive as Germany.

5.2 Factor Endowments and Industry Factor Intensity

As already discussed a core issue, which requires systematic treatment in a joint model is to identify the potential sources of productivity differences across countries. An extensive investigation of the sources of productivity differences across countries is a topic of research itself and certainly, it cannot be fully addressed in the present study. However, the present sub-section investigates whether forces proposed by H-O (i.e. factor endowments) are associated with forces proposed by the Ricardian theory. To implement this investigation, we specify a channel via which factor abundance is linked to industry's productivity.

The theoretical model in section (2) does not clearly state whether factor price equalisation (FPE) holds[25]. It is implicitly assumed that FPE holds and thus there is no need to examine what happens to the pattern of specialisation when factor prices differ across countries[26]. Davis and Weinstein (2001a) mention that FPE fails even among developed countries indicating that when factor rewards vary across countries, this has an effect on the type of goods that each country produces. Under some standard assumptions such as perfect competition, free trade, no transportation costs[27] and no qualitative differences in the factors of production, the only plausible explanation for the failure of FPE is in the differences of relative factor endowments[28]. An important implication of FPE failure is that national factor endowments can directly drive the choice of production inputs at the industry level. Schott (2003) formally represents that if countries experience high rates of capital accumulation then relative factor rewards are also affected. This will lead capital abundant countries to be systematically biased towards capital inputs in all sectors. Linking this statement with Romer's (1990) proposition that capital accumulation is a main source of technical progress then the resulting puzzle suggests that a country's capital abundance has an indirect positive influence on productivity at the industry level. In a similar line of argument, Acemoglu

[25] Harrigan (1997) attributes the existence of FPE to the fact that the dual translog revenue function is valid at all points in the sample.

[26] Interpreting this assumption in pure international trade theory terms, the fact that FPE holds implies that countries operate in a one cone-model. For further details, see Harrigan (2001).

[27] Romalis (2004) shows that the transportation costs can directly lead to FPE failure.

[28] Certainly, this set of assumptions should include that productivity of factors are the same across countries. For the purposes of the current analysis, productivity is modelled as industry specific and thus national factors are not adjusted in productivity units.

(2002) illustrates that if countries are well endowed in skilled labour then their *TFP* is systematically higher in all industries.

The methodology that we apply does not directly prove whether sectoral productivity is a function of factor endowments. Instead, we use equation (10) to test the hypothesis of whether national factor endowments determine industry factor intensity[29]:

$$\left(\frac{K}{L}\right)_{i,c,t} = b_0 + b_1\left(\frac{K}{L}\right)_{c,t} + n_c + h_t + u_{i,c,t} \qquad (10)$$

where the left hand side of the regression represents the capital–labour ratio in industry i of country c at year t. The right-hand side of (10) includes the aggregate capital-labour ratio of the country plus a group of country and year fixed effects. Using OLS, (10) is estimated industry-by-industry after pooling observations over countries and years. Specification (10) is not derived from a well-specified structural model but, it has an interesting economic intuition; if the estimated coefficient b_1 is significantly different from zero then, there is evidence that national factor abundance is associated with industry's factor intensity. In other words, country's abundance drives the choice of production techniques at the disaggregate level. If the estimated b_1 is zero, then there is support for the hypothesis that aggregate factor supplies are uncorrelated with factor intensity at the industry level; hence the H-O propositions do not bias the Ricardian forces in determining the sources of specialisation.[30]

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[29] This regression was suggested by Harrigan (2001) indexed as equation (25).

[30] Equation (10) is also an empirical test for the factor price insensitivity (FPI) effect. A positive beta coefficient implies that changes in relative factor endowments have an effect in factor prices. On this base, increases in the national capital-labour ratio means that price of capital services is relatively cheaper and thus individual industries find optimal to substitute labour with capital inputs.

Table 6 National Factor Endowments and Industry Factor Intensity

Industry	*K/L*	N	R-squared
Food Products	0.192	75	0.81
	(1.79)		
Textiles	0.008	75	0.89
	(0.11)		
Wood	-0.264	60	0.8
	(0.82)		
Pulp and Paper	-0.158	75	0.66
	(1.06)		
Coke	-0.174	75	0.81
	(0.95)		
Chemicals	-0.055	75	0.67
	(0.42)		
Rubber	-0.103	75	0.65
	(0.93)		
Other non-metallic	0.273	75	0.85
	(1.33)		
Basic Metals	0.229	75	0.78
	(1.21)		
Machinery	-0.131	75	0.69
	(1.67)		
Electrical	-0.076	75	0.58
	(0.54)		
Transport	-0.012	75	0.67
	(0.10)		
Manufacturing	-0.053	75	0.86
	(0.44)		

Notes:
The dependent variable is the capital labour ratio at the industry level and the column reports estimates for the coefficient of the aggregate capital-labour (*K/L*) ratio. Parentheses report t-statistics from OLS estimation with robust standard errors clustered by country.

Results from table (6) clearly suggest that national endowments are not correlated with industry factor intensity. The insignificant estimated coefficients indicate that there is no sensitivity between a change in the aggregate relative factor supply and the use of this factor at the industry level. Intuitively, countries that are more capital abundant are not necessarily biased towards capital-intensive techniques and thus national factor endowments cannot drive productivity at the industry level. This evidence differs from findings of previous studies (Davis and Weinstein (2001b)), which estimate an equation similar to (10). Furthermore, the lack of significant evidence between aggregate factor endowments and industry factor intensity is an indirect signal that FPE holds across countries of the present sample. More precisely there maybe factor price differences across countries but they are too small to drive the pattern of specialisation. This is a reasonable hypothesis considering that the sample includes European countries with very similar levels of development. Nonetheless, any generalisation of the above statement should be done with caution as Davis and Weinstein suggest (2001a, Figure 1) wage differentials can be large even among OECD developed countries.

This result enables us to assume that H-O and Ricardian effects have their own contribution to the pattern of specialisation and the estimation of a joint model is meaningful. Morrow (2006) seeks to provide a formal proof whether H-O and Ricardian forces are interrelated by conducting a more direct correlation test between industry factor intensity and *TFP*. The conclusions emerged from Morrow (2006) are in the same line with the results provided here signifying that H-O and Ricardian effects are independent in determining the pattern of specialisation. In the present study, the lack of correlation between national factor endowments and industry factor intensity is undoubtedly a convenient result for the following empirical exercises of the paper. In general, this issue should be always under investigation as the outcome strongly depends on the data set under study.

5.3 Estimating of a Joint Model of Specialisation

The next step is the estimation of a joint model that includes both productivity and relative factor endowments as determinants of specialisation. The structural form of the model is based on equation (6) in the previous section. The parameter q is the *TFP* index measured by formula (9). The estimable equation takes the following form:

$$s_{i,c,t} = b_{0i,c} + b_1 TFP_{i,c,t} + b_2 \log\left(\frac{K}{L}\right)_{c,t} + b_3 \log\left(\frac{SL}{L}\right)_{c,t} + b_4 \log\left(\frac{A}{L}\right)_{c,t} + b_5 \log\left(\frac{E}{L}\right)_{c,t} + u_{i,c,t} \qquad (11)$$

The only difference between specifications (7) and (11) is that *TFP* is now included in the right –hand side of equation. The model also includes country and year fixed effects and estimated industry- by- industry using SUR.

Table 7 Output Shares, *TFP* and Factor Endowments

Industry	*TFP*	*K/L*	*SL/L*	*A/L*	*E/L*	H.R chi2 (5)	N	R-squared
Food Products	0.10***	0.12	-0.41***	0.12	0.17**	173	55	0.8
	(3.68)	(0.96)	(3.71)	(1.39)	(2.23)			
Textiles	0.05***	-0.046	-0.27**	-0.043	0.041	117	55	0.71
	(3.06)	(-0.36)	(2.39)	(0.47)	(0.53)			
Wood	0.031	-0.152	-0.048	0.14*	-0.36***	1144	55	0.96
	(1.26)	(1.37)	(0.48)	(1.89)	(5.43)			
Pulp and Paper	0.06***	0.007	-0.37***	-0.11	-0.19**	141	55	0.77
	(3.68)	(0.047)	(2.63)	(0.99)	(1.96)			
Coke	0.19***	1.05***	-1.37***	0.25	0.33*	312	55	0.84
	(5.77)	(3.73)	(5.44)	(1.22)	(1.90)			
Chemicals	0.08***	0.77***	-0.79***	0.27*	0.48***	377	55	0.87
	(3.68)	(3.76)	(4.32)	(1.86)	(3.84)			
Rubber	0.06**	0.254	-1.45***	0.85***	0.46***	145	55	0.75
	(2.21)	(0.97)	(6.23)	(4.51)	(2.95)			
Other non-metallic	-0.019	0.53***	0.77***	-0.019	0.10*	528	55	0.91
	(0.91)	(5.83)	(9.16)	(0.30)	(1.92)			
Basic Metals	-0.043***	-0.36***	0.09	-0.014	-0.084	302	55	0.91
	(3.30)	(3.69)	(1.10)	(0.21)	(1.41)			
Machinery	-0.01**	-0.64**	2.04***	-1.37***	-1.06***	387	55	0.89
	(2.43)	(2.07)	(7.39)	(6.10)	(5.69)			
Electrical	0.00	0.51***	-0.19	0.34***	-0.00	319	55	0.86
	(0.33)	(3.35)	(1.46)	(3.10)	(0.090)			
Transport	-0.021**	-0.47***	0.008	-0.36***	-0.039	1255	55	0.96
	(1.99)	(6.39)	(0.13)	(6.65)	(0.88)			
Other Manufacturing	-0.086	-1.73***	1.51***	-1.24***	-1.04***	64	55	0.63
	(1.01)	(3.45)	(3.55)	(3.50)	(3.57)			
S.R chi2 (12)		191.98	481.47	289.97	446.39			

Notes:
Coefficients are standardised beta coefficients and absolute t-statistics in parentheses; The asterisks correspondence is *significance at 10%;**significance at 5%;***significance at 1%. Each equation includes a set of country and year dummies (estimates are not shown for brevity). Observations are weighted by the inverse of GDP to account for group-wise heteroscedasticity. The homogeneity restriction (**H.R**) refers to the hypothesis: $\mathbf{H_0}: b_1 = b_2 = b_3 = b_4 = b_5 = 0$ (i.e. coefficients of *TFP* and factor endowments are jointly zero in each equation). The symmetry restriction (**S.R**) tests the hypothesis that factor endowments have the same effect across equations $\mathbf{H_0}: b_{1,i} = b_{1,j}$ for *i*?*j*.

Table (7) is organised in the same way as table (3), each row corresponds to an industry and each column corresponds to an independent variable. The third column from the end refers to a homogeneity restriction testing whether *TFP* and relative factor endowments are jointly zero in each industry. The last row tests the restriction whether the effect of a particular factor endowment is the same across industries. Wald statistic is used to test both hypothesises, thus Chi-square values are reported.

The first column refers to the effect of *TFP* across industries, which is positively signed in 8 out of 13 industries while in seven of them; the coefficient is significant at high statistical levels. *TFP* is a significantly positive determinant of specialisation mainly in the so-called low and medium technology industries while in some of the traditionally high-technology industries the estimated coefficient has a negative sign. Given that all variables in (11) are expressed in logarithms, it allows us to give a more direct interpretation of the coefficients. For example, a one percent increase in *TFP* in textiles leads to 5.2 percent increase in industry's output share. The strongest effect of *TFP* is observed in the coke industry, in which a one percent increase in *TFP* raises output share by 19.6 percent.

Turning to the estimated effect of relative factor endowments, the relative capital labour abundance, (*K*/*L*), remains an important source of specialisation but only in industries that use this factor intensively. The first remark about capital-labour ratio is that the estimated coefficient is now significant in a smaller number of industries compared to table (3) (i.e. four out of thirteen). However, there is a perfect match between industries with a positive estimate of capital abundance and their associated factor intensity in table (5). In the latter table, industries of coke, electrical and chemicals are the most capital intensive of the sample and the estimated coefficient of (*K*/*L)* in these industries is positive and statistically significant. To understand better the economic significance of the above estimates, the standardised beta coefficients are reported. Beta coefficients indicate the expected change in standard deviation of the dependent variable after a one standard deviation change in the independent variable (Leamer (1984)). According to this interpretation, the most significant effect of capital abundance is documented on the coke industry in which a one standard deviation increase in capital abundance increases output share by 1,05 standard deviations. Conversely, the strongest negative effect is found in other manufacturing in which a one standard deviation increase of capital abundance decreases industry's output share by 1.73 standard deviations.

For skilled labour abundance (*SL*/*L*) it is difficult to recognize to what degree the estimates produced are consistent with the actual factor intensity because there is no information for industry's skilled labour intensity for all countries. However, the pattern emerged from table (7) provides a powerful inference: skilled labour abundance is not a source of comparative advantage in manufacturing industries. In six out of the thirteen industries, the estimated coefficient of skilled labour ratio is negative and statistically significant while only in three industries, the skill abundance has a positive and significant effect on industry's share to country's GDP. These findings confirm a general tendency documented also in other empirical studies (Leamer (1984), Harrigan (1995), Redding (2002) and Reeve (2006)). The most prominent story hidden behind this negative effect implies that the nature of manufacturing jobs do not generally require highly educated workers, thus when labour inputs are driven from other sectors of the economy to manufacturing, this comprises losses of competitiveness for manufacturing industries (Harrigan (2001)).

It is difficult to identify a clear relationship between land abundance (*A*/*L*) and comparative advantage. In contrast to common beliefs, abundance of arable land is of minor importance in the food industry, while in the other natural resource oriented industry, wood, a positive effect is present. In high-technology industries of machinery and transport equipment, land abundance is clearly a source of disadvantage; however, the coefficient of arable land is unusually positive and significant in electrical industry.

Finally, the last column of table five presents the effects of energy abundance (*E/L*) on the pattern of specialisation. Considering the energy intensity at the industry level (table (5)), the ranking indicates that coke, chemicals, rubber and plastics and other non-metallic industries are relatively the most intensive industries in the use of energy. Energy abundance carries a positive coefficient in these four industries. On the contrary, industries ranked as less energy intensive have a negative coefficient. A striking result emerged from table (7) is that in the industries of transport and basic metals, we cannot identify any significantly positive determinant of specialisation. The current availability of production inputs at the industry level does not allows us to investigate what type of factors used intensively in these industries. Although, one might expect that capital abundance should have been a positive determinant of output share at least in the transport industry, which uses quite intensively that factor (see table (5)) Apart from this inconclusive point, the overall evidence from table (7) clearly indicates that the H-O mechanisms are evident in the present sample.

Regarding the test of the homogeneity restriction, the chi-squared values clearly suggest that the hypothesis that *TFP* and factor endowments coefficients are jointly zero is rejected at high statistical levels. The intuitive interpretation of this outcome advocates that a joint specification performs well, an argument that can be also supported by the high R-squared values. Especially, the latter statistic signifies that both H-O and Ricardian forces explain much of the variation of industry's output share. The test of symmetry restrictions presented in the last row rejects the null at high statistical levels indicating that the impact of factor endowments differ across industries. This result accords with the main priors of the Rybczynski theorem highlighting that the impact of national factors supplies across industries depends on how intensively industries use these factors.

6. Sensitivity Analysis-Further Specifications

Another important issue involved in estimating (11) is to what degree unobservable and chronic errors in the measurement of the variables used can give biased estimates. For national factor supplies, a central issue is whether quality differences that are excluded from the current definitions are sources of serious bias in the econometric results. For instance, current definitions do not take into account climate conditions in the measure of land or differences in the years of schooling in the measure of labour. A common attribute of the above effects is that most (if not all) of them are fixed across time and to some extent their impact on the pattern of specialisation can be effectively captured via country fixed effects.[31] Another issue is that the PPP-exchange rate is based on prices of aggregate output instead of prices of a more disaggregate level. O' Mahoney (1996) notes that the relative *TFP* measures can vary substantially according to the PPP-exchange rate used for conversion implying that researchers should always have in mind that *TFP* indices are subject to measurement errors. The ideal solution to any measurement problem is the use of an instrumental variable approach. Valid instruments for factor supplies are almost impossible to find. However, recognising the positive role of research and development (R&D) on promoting *TFP*, the one year lagged of R&D share is used as instrument for the *TFP* variable. Moreover, if one considers that technology is mobile across industries within a country then can be used as instrument of industry *i*'s *TFP* the average *TFP* of all other industries in country *c*[32]. This set of instruments is defined as:

$$\frac{1}{T-1}\sum^{T-1} TFP_{j,c,t} \ \ where\ j \neq i$$

[31] Klepper and Leamer (1984) suggest that classical errors in the measurement of factor endowments are bounded and can be viewed as a function of regression's R^2. In the current estimations, R^2 is high in all industries indicating that any problem might occur from measurement errors is small.

[32] For these instruments to be valid a further assumption needs that while *TFP* across industries are correlated, *TFP* errors are not. A similar argument can be also found in Harrigan (1997), but in his case as instruments of *TFP* in industry *i* is used the average *TFP* of this industry across all countries in the sample.

Table 8 Determinants of Output Share from 2SLS Estimation

Industry	*TFP*	*K/L*	*SL/L*	*A/L*	*E/L*	**H.R**	N	Adj. R-squared
Food Products	0.108	0.117	-0.41***	0.123	0.169*	20.2	55	0.80
	(1.52)	(0.72)	(2.87)	(1.08)	(1.73)	(0.00)		
Textiles	0.114***	-0.174	-0.198	-0.126	-0.009	15.0	55	0.73
	(2.90)	(0.98)	(1.33)	(1.01)	(0.084)	(0.00)		
Wood	0.071*	-0.200	0.000	0.120	-0.38***	141.9	55	0.96
	(1.85)	(1.40)	(0.0021)	(1.19)	(4.47)	(0.00)		
Pulp and Paper	0.103**	-0.036	-0.346*	-0.132	-0.204	16.6	55	0.78
	(2.04)	(0.17)	(1.90)	(0.90)	(1.64)	(0.00)		
Coke	0.293**	1.027***	-1.39***	0.178	0.345	35.6	55	0.84
	(2.38)	(2.84)	(4.31)	(0.64)	(1.55)	(0.00)		
Chemicals	0.293**	0.630**	-0.69***	0.192	0.436***	46.8	55	0.88
	(2.38)	(2.31)	(2.89)	(0.99)	(2.70)	(0.00)		
Rubber	0.148**	0.078	-1.31***	0.713***	0.399*	18.4	55	0.76
	(2.38)	(0.23)	(4.26)	(2.79)	(1.94)	(0.00)		
Other non-metallic	0.007	0.518***	0.80***	-0.029	0.103	65.2	55	0.91
	(0.22)	(4.44)	(7.38)	(0.34)	(1.44)	(0.00)		
Basic Metals	-0.063**	-0.34***	0.067	-0.001	-0.078	37.3	55	0.91
	(2.54)	(2.68)	(0.57)	(0.0084)	(1.01)	(0.00)		
Machinery	-0.141**	-0.53	1.958***	-1.29**	-1.02***	48.3	55	0.89
	(2.33)	(1.30)	(5.46)	(4.40)	(4.25)	(0.00)		
Electrical	0.033	0.466**	-0.165	0.311**	-0.027	39.7	55	0.87
	(1.09)	(2.35)	(0.94)	(2.20)	(0.23)	(0.00)		
Transport Equipment	-0.024	-0.47***	0.005	-0.35***	-0.038	155.3	55	0.96
	(1.64)	(4.97)	(0.053)	(5.17)	(0.66)	(0.00)		
Manufacturing	-0.281**	-1.278*	1.278**	-0.957**	-0.873**	8.7	55	0.65
	(2.14)	(1.92)	(2.33)	(2.06)	(2.30)	(0.00)		
S.R		6.5 (0.00)	12.4 (0.00)	5.4 (0.00)	5.3 (0.00)			

Notes:

Coefficients are standardised beta coefficients and absolute t-statistics in parentheses; The asterisks correspondence is *significance at 10%;**significance at 5%;***significance at 1%. Observations are weighted by the inverse of GDP to account for group-wise heteroscedasticity. The estimation applied is 2SLS using as instruments for *TFP* an one year lagged R&D share, average *TFP* of all industries in the country and a set of country and year dummies. Estimates from the endogenous equation are not reported to save space. The homogeneity restriction (**H.R**) refers to the hypothesis: $\mathbf{H_0}: b_1 = b_2 = b_3 = b_4 = b_5 = 0$ that coefficients of TFP and factor endowments are jointly zero in each equation;. The symmetry restriction (**S.R**) tests the hypothesis that factor endowments have the same effect across equations $\mathbf{H_0}: b_{1,i} = b_{1,j}$ for $i?j$. The p-values for the restriction tests are given in parentheses under the coefficients.

Table (8) shows the results from the 2SLS estimation and the use of instrumental variables for *TFP*. The main message derived from table (8) is the same as from table (5). Some differences occur in the significance of the estimates of all variables but the economic intuition of the results remains the same. *TFP* is positive and significant in six of the thirteen industries while *TFP* has a negative and significant coefficient in three industries. The estimated coefficient of capital and skilled labour abundance remains unchanged, while the effect of arable land in now significantly positive only in the rubber industry. Small differences are also revealed regarding the impact of energy abundance using a 2SLS estimation. The coefficient of this factor is not significant any more in the industries of coke and other non-metallic. Testing for homogeneity and symmetry restrictions provides the same results as in table (7).

A further check of robustness for the results presented in table (7) is to control for the speed of adjustment in the output share after a change in productivity and relative factor supplies. An underlying assumption of the neoclassical model is that there is free movement of the factors of production across industries within the same country. In a more realistic setting, the implementation of this reallocation takes time. This implies that an increase (or decrease) in industry *i*'s TFP needs a certain period to reflect an increase (or decrease) in industry *i*'s output share. A similar effect is at work for changes in relative factor endowments. A possible way to allow for time adjustment in the model is to estimate (11) by taking all the right-hand side variables in one year lags. Harrigan (1997) controls for slow adjustment and persistence in industrial structure adding a dependent variable in the right-hand side of his empirical specification. In the current model, this dynamic specification is rather problematical since the time span of the panel is relatively short and an OLS estimation of (11) is likely to give a downward biased estimate for the coefficient of the lagged dependent variable (Hsiao (1986)). Due to this inconsistency, slow adjustment in the model is accounted for by lagging all the right –hand side variables.

Table 9 Output Share and Lagged TFP

Industry	L1.TFP	L1.*K/L*	L1.*SL/L*	L1.*A/L*	L1.*E/L*	**H.R**	**N**	**Adj. R-squared**
Food Products	0.08***	0.08	-0.40***	0.09	0.14*	163.6	51	0.790
	(2.82)	(0.66)	(3.55)	(1.05)	(1.79)	(0.00)		
Textiles	0.04**	0.04	-0.30***	0.02	0.093	110.79	51	0.720
	(2.42)	(0.32)	(2.58)	(0.29)	(1.14)	(0.00)		
Wood	0.034	-0.171	0.031	0.117	-0.38***	1236.9	51	0.960
	(1.59)	(1.49)	(0.30)	(1.46)	(5.48)	(0.00)		
Pulp and Paper	0.057***	0.091	-0.363**	-0.069	-0.149	136.2	51	0.760
	(3.19)	(0.53)	(2.39)	(0.57)	(1.42)	(0.00)		
Coke	0.219***	1.054***	-1.35***	0.232	0.33*	274.5	51	0.830
	(5.35)	(3.36)	(4.86)	(1.04)	(1.76)	(0.00)		
Chemicals	0.065***	0.81***	-0.77***	0.277*	0.49***	363.2	51	0.880
	(2.82)	(3.68)	(4.01)	(1.79)	(3.70)	(0.00)		
Rubber	0.055**	0.619**	-1.52***	1.111***	0.68***	178.2	51	0.790
	(2.21)	(2.38)	(6.65)	(6.00)	(4.36)	(0.00)		
Other non-metallic	-0.004	0.325***	0.86***	-0.168**	0.002	442.8	51	0.900
	(0.19)	(3.19)	(9.26)	(2.33)	(0.035)	(0.00)		
Basic Metals	-0.02**	-0.42***	0.068	-0.041	-0.128*	232.7	51	0.890
	(2.04)	(3.72)	(0.66)	(0.51)	(1.82)	(0.00)		
Machinery	-0.10***	-0.831**	2.02***	-1.46***	-1.18***	373.2	51	0.890
	(2.83)	(2.41)	(6.73)	(6.02)	(5.74)	(0.00)		
Electrical	0.002	0.75***	-0.129	0.44***	0.126	349.3	51	0.880
	(0.093)	(4.66)	(0.92)	(3.94)	(1.29)	(0.00)		
Transport	-0.009	-0.59***	-0.037	-0.40***	-0.11**	1012.3	51	0.950
	(0.76)	(6.74)	(0.47)	(6.49)	(2.08)	(0.00)		
Manufacturing	-0.19**	-1.52***	1.03**	-0.99***	-1.03***	65.16	51	0.660
	(2.24)	(2.78)	(2.30)	(2.64)	(3.24)	(0.00)		
S.R		178.46	442.88	311.19	451.51			
		(0.00)	(0.00)	(0.00)	(0.00)			

Notes:
Coefficients are standardised beta coefficients and absolute *t*-statistics in parentheses; The asterisks correspondence is *significance at 10%;** significance at 5%;***significance at 1%. Observations are weighted by the inverse of GDP to account for group-wise heteroscedasticity. All variables are lagged by one year to allow for slow adjustment. The homogeneity restriction (**H.R**) tests the hypothesis: $\mathbf{H_0}: b_1 = b_2 = b_3 = b_4 = b_5 = 0$ that coefficients of *TFP* and factor endowments are jointly zero in each equation;. The symmetry restriction (**S.R**) tests the hypothesis that factor endowments have the same effect across equations $\mathbf{H_0}: b_{1,i} = b_{1,j}$ for *i?j*. The *p*-values for the restriction tests are given in parentheses under the coefficients

Table (9) reveals that there are no remarkable differences even after allowing for time adjustment in productivity and factor supplies. The effects of *TFP*, capital and skilled labour endowments are almost identical to that depicted in table (7). The coefficient of arable land in wood industry becomes now insignificant while the effect of arable land in the electrical industry preserves a peculiar positive coefficient. No notable differences occur regarding the abundance of energy, which maintains the same sign across industries as in previous specifications with some minor changes in the t-values of the estimated coefficients. Results from table (9) provides an additional confirmation that controlling for lag in output share responses after changes in *TFP* and factor endowments does not cause remarkable differences in the estimates.

7. Discussion-Conclusions

This chapter contributes to the existing literature in a number of different aspects. The main goal of the chapter is to analyse what factors determine the industrial structure in six EU countries. A second important contribution of the paper is to assess the validity of the H-O theory of trade. The implementation of the above tasks is attained with an articulated model that jointly estimates the contribution of H-O and Ricardian forces in the pattern of specialisation. The third contribution of the paper lies in the estimation of this joint model, which has attracted little attention in the literature despite the common belief that both H-O and Ricardian predictions matter.

The identification of the determinants of industrial specialisation is equivalent to investigating the sources of comparative advantage across industries. Clearly, there is no a single study that can provide definite answers to such a complicated and crucial issue. The present study points out some new directions in how researchers should investigate the sources of comparative advantage and specialisation. This new directions can provide valuable assistance towards a more effective economic policy.

A significant amount of papers apply partial equilibrium approaches to identify the determinants of industrial structure. The underlying argument of these approaches is that specialisation is exclusively governed by industry specific characteristics. However, this scenario is incomplete since it systematically excludes the general equilibrium effects on individual industries. The present study analyses the pattern of specialisation within a general equilibrium framework including factors that both reflect national endowments and industry's individual performance. The H-O and Ricardian models formally represent these separate factors. A joint model provides useful guidance for the contribution of each model to the pattern of specialisation, assisting vitally to the design of an appropriate policy. To clarify this contribution consider that a particular policy is issued to foster competition in non-metallic and machinery industries (table (7)) seeking to increase an industry's overall productivity. This policy is likely to be ineffective since the positive determinant of specialisation in these industries is country's capital and skilled labour abundance rather than industry's individual TFP performance. This indicates that the policy suggested should be modified and takes into account the impact of aggregate factor supplies on industry's output.

The empirical estimation of the model is implemented in stages. The first stage refers to a model that excludes productivity as a source of specialisation. This specification corresponds to a static Rybczynski-type effect, which is the equilibrium representation of the H-O theory. An interesting extension of the Rybczynski equation is also implemented for the case of Greek bilateral trade. Estimated coefficients from both the production and the trade version of the model correspond to the actual industry factor intensities indicating that the H-O model performs quite well.

The estimation of a joint model enhances some remarkable complications that need special treatment in order to make the implementation of the model meaningful. The key issue examined is whether factor price equalisation (FPE) holds, as this is the prerequisite that ensures independence between national factor abundance and disaggregate productivity. Due to the nature of the countries currently in the sample, the condition of FPE is not violated allowing us to proceed with a joint estimation. Results from this estimation reveal that both factor endowments and productivity matter in the determination of the comparative advantage.

Undoubtedly, there are still many unexplored issues in order to say that we understand perfectly the pattern of specialisation. The current analysis offers support for the empirical validity of a joint model but the specifications used throughout the chapter face some limitations. One of them is the lack of a well-specified alternative scenario for the pattern of specialisation. Many studies that seek to assess the validity of the international trade theories encounter this standard problem (Harrigan (2001)). Harrigan and Zakrajšek (2000) and Fitzgerald and Hallak (2004) consider as alternative hypothesis that movements in country's overall productivity can increase industry's output. This alternative view can be easily accommodated in the present analysis constituting an interesting extension to the present specifications.

The specifications estimated in the paper represent mainly static effects of specialisation providing no information for how comparative advantage changes endogenously over time. Helpman (1998) mentions that the global economy changes radically stressing the need for new developments in international trade theory that will provide insights for the dynamic changes in the nature of comparative advantage.

Endogenous growth theory suggests that comparative advantage of a country is likely to be determined by accumulation of knowledge or trade. According to these effects, the pattern of specialisation preserves persistency and it is subject to international knowledge spillovers. Redding and Proudman (2000) and Redding (2002) investigate the dynamics of specialisation addressing some of the above effects systematically. Examining the dynamics of specialisation can offer plausible answers regarding changes in the pattern of production over time. For instance, if an industry has a persistently small output share, what is the probability for this industry to remain as such after a given period. Certainly, these issues constitute interesting paths for future research.

Differences in technology in the Ricardian model are viewed as exogenous. This simplistic assumption is not adopted any more and an intensive research is carried out to investigate the sources of international productivity differences. The present analysis restricts this investigation to analysing the extent to which national factor endowments dictate the mix of inputs at the micro level; however, it does not explain, for example, why Germany is more productive in the transport industry than Spain. By drawing clear conclusions for which factors have a clear impact on productivity differentials across countries, the mechanisms driving the puzzle of international specialisation will be more visible. Parts of these issues are examined in chapter 4 of the thesis.

Appendix 1

Data for Factor Supplies are taken from World Bank Indicators and UNESCO. The former source provides country level data for energy production, capital and arable land, while the latter provides estimates for each country's labour force by educational level. Many countries do not conduct labour surveys on an annual base and thus many missing values are reported in labour data. Missing values are filled using a linear interpolation procedure. Assuming that changes in educational level of labour force is a linear function of time then missing numbers within a time interval are filled with the mean value of non-missing numbers, the manual of Stata 8 provides further details for the interpolation procedure. Flow data on fixed capital assets and inventories are reported in US dollars but the measure used in the empirical analysis is capital stock calculated by using a standard perpetual method. The formula is identical to the one used in the construction of capital stock at the industry level.

The OECD-STAN is the main provider of industry level data but some additional information is taken from the Groningen Growth and Development Centre (GGDC). STAN provides industry level data in ISIC Rev.3 classification for the following variables: value added, value added deflator, labour compensation of employees, number of employees, Gross fixed capital formation and capital deflator. Data for R&D are also used to instrumentalise the TFP variable, data for R&D for all countries except for Greece are obtained from OECD-R&D expenditure in industry database, while for Greece are taken from OECD –Total Intramural expenditure on R&D (13r3). R&D figures are reported in PPP-USD. The STAN database reports missing values for capital and value added deflators. In order to avoid dropping observations with missing values, missing numbers are filled with data taken from GGDC (60-Industry database) and GGDC (KLEMS). Data for hours worked per employee, intermediate energy inputs and their associated index deflators are taken by GGDC (60-Indsutry database) and GGDC (KLEMS), respectively. Industry data for Germany before 1991 refer only to Western Germany. Data for capital and the number of employees in Greek industries starts from 1995, so data for prior years are taken exclusively from GGDC (KLEMS). Initially all data are reported in national currency (i.e. Euro for Euro-zone countries and GBP for UK), these are converted to USD using PPP-exchange rates (see the text for more details). The table below summarises the variables used in the study and their data sources.

Appendix 2 Summary of Data Sources

Period	1987-2003 (Industry data series finishes in 2002)	
Countries	France, Germany, Greece, Italy, Spain, UK	
Trade flows	Bilateral Trade Data Base	OECD-STAN
Industries- ISIC (Rev.3)	Food products, beverages and tobacco Textiles, textile products, leather and footwear Wood and products of wood and cork Pulp, paper, paper products, printing and publishing Coke, refined petroleum products and nuclear fuel Chemicals and chemical products Rubber and plastics products Other non-metallic mineral products Basic metals and fabricated metal products Machinery and equipment, nec Electrical and optical equipment Transport equipment Manufacturing nec	OECD-STAN and GGDC (60-Industry Database and KLEMS)
Industry- Variables	Value, added, Labour Compensation, Number of Employees, Gross fixed Capital formation, Intermediate Energy Inputs, Hours Worked, R&D expenditure, Capacity utilisation (Values are expressed in USD)	
Factor Supplies Land: Hectares of Arable land, km^2 of forest land is also used Energy: production of energy converted into KG of oil equivalent Capital: Stock from capital fixed assets is constructed via an inventory method		World Bank Developmen Indicators World Bank Developmen Indicators World Bank Developmen Indicators
Labour classified by Educational Level: • Low Skilled- Number of Workers with primary education • Medium- Number of Workers with secondary education • High- Number of Workers with tertiary education • Total labour	• Less-Skilled labour: Share of workers with primary and secondary education • Skilled labour: Share of Workers with tertiary education	UNESCO Estimates
PPP- Exchange Rate	National Currency to USD	World Bank Indicators –International Comparison Project (ICP)

Appendix 3 Shares of Greek Trade with Five EU Countries

Partner	Import Share Compared to EU-15	Export Share to EU-15	Import Share Compared to Total World	Export Share to Total World
France	0.117	0.103	0.081	0.058
Germany	0.261	0.344	0.181	0.193
Italy	0.232	0.215	0.161	0.119
Spain	0.049	0.045	0.033	0.023
United Kingdom	0.088	0.135	0.061	0.072
Total	0.75	0.84	0.52	0.47

Appendix 4 Average TFP 1987-2002 Relative to Germany

Industry	France	Greece	Italy	Spain	UK	Germany
Food	116.8	31.9	96.8	70.1	77.0	100
Textiles	103.4	21.7	81.5	50.7	35.0	100
Wood	109.4	25.4	67.7	43.5	52.9	100
Pulp and paper	100.9	27.9	85.9	54.7	55.2	100
Coke and petroleum	197.7	60.1	135.7	209.4	47.7	100
Chemicals	98.0	23.3	80.9	51.1	41.1	100
Plastics	74.9	12.4	64.0	49.9	26.8	100
Other non-Metallic	91.2	23.3	72.7	52.6	61.1	100
Basic metals	78.2	18.1	62.3	36.8	40.3	100
Machinery	74.6	6.2	63.1	39.1	22.8	100
Electrical	75.0	11.6	56.8	34.2	29.0	100
Transport	58.2	23.6	47.7	30.3	25.2	100
Manufacturing	88.3	17.3	76.9	46.4	29.6	100

Notes:
Productivity levels are expressed relative to Germany. For example, Spain's TFP level in Food industry is 70 % of Germany's TFP level in this industry. Similar interpretation can be applied to all TFP numbers

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