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HOV with technology and consumption dissimilarity[☆]

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Abstract

It is now widely accepted that when controlling for international differences in production techniques the predictions from the Heckscher-Ohlin-Vanek (HOV) theorem are largely satisfied. However, a large amount of 'missing trade' remains. The aim of this paper is twofold: First, the HOV is tested for various production factors including labor by educational attainment levels (high, medium, low) and capital. Second, when allowing for a more general structure of final consumption in the HOV framework with technology differences the amount of missing trade is reduced. We test for the effects of non-homothetic preferences, home-bias of consumption and the role of distance at the country and industry level. We discuss how this can be tackled in the analytical framework both for a country's total exports but also in a bilateral way. Results are shown both for total trade and bilateral trade. Empirically we draw on the recently released World Input-Output Database (WIOD) and show the reductions in the 'missing trade' caused by the various assumptions and restrictions on demand structures.

JEL: F1, F15, F19

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1. Introduction

It is now widely accepted that when controlling for international differences in production techniques the predictions from the Heckscher-Ohlin-Vanek (HOV) theorem are largely satisfied (Trefler, 1993, 1995; Davis and Weinstein, 2001; Reimer, 2006; Trefler and Zhu, 2010; Nishioka, 2012). However, there still remains a large amount of 'missing trade', i.e. predicted flows of factors are much larger than the measured ones. Further, most of the recent papers tested the HOV with only one factor, an exception being Nishioka (2012) including capital and labor. There is of course an older literature including many more factors (for an overview see Foster and Stehrer, 2010).

The aim of this paper is therefore twofold: First, the HOV is tested for various production factors including labor by educational attainment levels (high, medium, low) and capital. Second, as technology differences are accounted for the 'missing trade' is caused by an imperfect modeling of demand structures. Thus, this paper allows for a more general structure of final consumption in the HOV framework with

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technology differences and shows to which extent various assumptions on demand structures reduce the difference between actual and predicted flows of factor services. Particularly, we test for the effects of non-homothetic preferences, home-bias of consumption, and the relevance of distance at the country and industry level. Analytically, we discuss how this can be tackled in the analytical framework both for a country's total exports but also in a bilateral way as suggested in Hakura (2001). Empirically we draw on the recently released World Input-Output Database (WIOD) and show the reduction in missing trade due the various assumptions on demand structures.

The paper goes as follows. Section 2 provides a short description of the data used in this study, the world input-output database (WIOD). Section 3 introduces the framework as suggested by Trefler and Zhu (2010) to test the HOV model with technology differences and traded intermediates. This framework is extended to allow for non-homothetic preferences and allowing for non-proportional sourcing structures of final demand. Further, the HOV theory is tested for various inputs. Section 4 then provides a similar set of results when testing the HOV in a bilateral way. Section 5 concludes.

2. The world input-output database (WIOD)

The analysis requires data on output and the use of intermediates and production factors by industry. In this section we provide information on a recently constructed database, the World Input-Output Database (WIOD), that is used to study the value added and factor content of trade (see www.wiod.org). This is derived from national supply and use or input-output tables which are combined with detailed trade data resulting in a World Input-Output Table (WIOT). At the industry level the data are combined with further information obtained from Socio-Economic Accounts data (SEAs). The WIOTs are therefore a combination of national input-output tables in which the use of products is broken down according to their country of origin, national supply and use tables and detailed trade data. The information is collected on an annual basis from 1995 to 2009 for 59 products and 35 industries. The industry classification follows the ISIC Revision 3 classification for Non-EU countries compatible to NACE Rev. 1.1 which is used for EU countries. The data cover 40 countries which account for about 85 percent of world GDP.[1] The variables from the SEAs include gross output and value added, final demand expenditures, as well as employment by educational attainment, and capital compensation. The remainder of this section provides a more detailed overview of the construction of the SEAs and the WIOTs. A detailed documentation is provided in Timmer et al. (2012).

3. The factor content of trade with traded intermediates

In the calculations of the factor content of trade we follow the recent literature that includes the international flows of intermediates in the factor content of trade calculations. There is a tradition on how to incorporate traded intermediates into the Heckscher-Ohlin-Vanek framework starting with Staiger (1986) and Deardorff (1982). Recently this was discussed particularly by Reimer (2006) and was more recently tackled by Trefler and Zhu (2010) and Nishioka (2012). We outline the latter approach in this section and also discuss our approach to allow for different consumption patterns. This was emphasized in Linder (1961) and more recently in Markusen (1986), Maskus (1985), Maskus and Nishioka (2009), and Nishioka (2010). Staiger et al. (1987) tested for effects of trade barriers but found no significant improvements.

[1]These countries are the EU-27 plus Turkey, Canada, USA and Mexico, Japan, Korea, Taiwan, Australia, Brazil, Russia, India, Indonesia and China.

3.1. Methodological aspects

The calculation of the factor content of trade starts from the international input-output table and the corresponding coefficient matrix denoted by $\mathbf{A}$ which is of dimension $NG \times NG$ where N denotes the number of countries and G is the number of industries. As the WIOD data include $N = 40$ countries and $G = 35$ industries the dimension of this matrix is 1435×1435. Using the corresponding data on inputs (i.e. capital, low, medium and high educated workers) one obtains a direct input coefficient matrix for each of these four factors by country and industry denoted by $\mathbf{D}$. $\mathbf{D}$ is of dimension $F \times NG$ with F being the number of factors considered. Thus, for each factor the direct input coefficients vector is of dimension 1×1435. The direct plus indirect input coefficients matrix is given by pre-multiplying the Leontief inverse $(\mathbf{I} - \mathbf{A})^{-1}$ by the direct input coefficients matrix, i.e. $\mathbf{B} = \mathbf{D}(\mathbf{I} - \mathbf{A})^{-1}$ which is of dimension $F \times NG$. Following Trefler and Zhu (2010) the bilateral trade vector for each country r, $\mathbf{t}^r$ is written by including bilateral imports negatively and country r's total exports positively. Thus, for each country the trade vector is of dimension 1435×1 with positive entries of total exports by industry and imports from each other country, i.e. bilateral, in negative terms.

Following Trefler and Zhu (2010) and Deardorff (1982) the proper measure of the factor content of trade when intermediates are traded is then calculated as

$$\mathbf{t}_f^r = \mathbf{B}\mathbf{t}^r$$

Each element of this matrix, t_f^r shows the amount of a particular factor f of country r directly and indirectly used worldwide in production of country r's trade vector Trefler and Zhu (2010) argue that this is the 'Vanek-consistent' definition of the factor content of trade (see Theorems 1-3), i.e.

$$t_f^r = V_f^r - s^r V_f$$

where V_f^r is the country specific endowment of country r with factor f and $V_f = \sum_r V_f^r$ denotes world endowments of factor f. The share s_r is measured as gross domestic product less the value of the trade surplus, divided by world gross domestic product.[2] Trefler and Zhu (2010) argue that former contributions (with the exception of Reimer, 2006) suffer from being either incompatible with the Vanek-relevant definition of factor content of trade or are economically not meaningful. Incidentally, this definition dates back to Deardorff (1982). The necessary and sufficient condition for a Vanek prediction is $\mathbf{B}\mathbf{f}^r = s^r \mathbf{B}\mathbf{f}$ where $\mathbf{f}^r$ is country r's consumption vector (of dimension $NG \times 1$) and $\mathbf{f} = \sum_p \mathbf{f}^p$. This is referred to as 'strong consumption similarity': it implies homothetic preferences across countries and proportionality of consumption across countries, i.e. a country consumes a proportion s^r of the final goods produced by every country. Particularly, the Vanek prediction holds when allowing for technology differences across countries as is assumed throughout this paper. This can be compared to the standard HOV model assuming the same techniques across countries in which case the sufficient condition becomes $\boldsymbol{\iota}'\mathbf{f}^r = s^r \boldsymbol{\iota}' \sum_p \mathbf{f}^p$ Country r's consumption of goods is proportional to world consumption of that good but does not specify where the good is produced. A more restrictive assumption on technology therefore allows for a weaker form of consumption similarity.[3]

3.2. Imposing stronger restrictions on consumption

As in Trefler and Zhu (2010) the HOV model works well - when allowing for technology differences - but there is a significant amount of missing trade meaning that actual trade flows are much lower than

[2] Only here trade surpluses or deficits are accounted for.

[3] When restricting technology (e.g. to US technology) only 'weak consumption similarity' has to hold to assure Vanek consistency. Restricting technology in such a way however results in a poor performance of the HOV model as documented in the other contributions. We do not report these results which are however available upon request.

the predicted flows. Various explanations have been put forward to explain this 'missing trade', examples including a home bias of consumption, trade barriers, transport costs, etc. Of the various tests for missing trade the simplest one might be to regress the measured factor content of trade (FCT) on the predicted. A coefficient close to one would indicate that there is little missing trade and that trade flows in factor services are well explained. Since technology differences are already taken into account in this framework, the missing trade that exists results from an improper specification of consumption patterns. Trefler and Zhu (2010) account for missing trade by imposing consumption similarity for various industries (Agriculture, Food, Government, Construction). They show that this improves the predictive power of the model significantly showing up in a slope coefficient of 0.94 when imposing consumption similarity for all four sectors. Other papers like Cassing and Nishioka (2010) introduce a vector of deviations of predicted from actual patterns of trade flows in final goods to account for missing trade.

In this paper a different route is followed by imposing more structure on the consumption similarity condition. Lemma 1 in Trefler and Zhu (2010) states that for one factor it has to hold that $t_f^r - (V^r - \mathbf{b}'\mathbf{f}^r) = s^r(\mathbf{b}'\mathbf{f} - V)$, which after rearranging can be written as:

$$t_f^r - (V^r - s^r V) = s^r \mathbf{b}'\mathbf{f} - \mathbf{b}'\mathbf{f}^r$$

The necessary and sufficient condition for the Vanek prediction ('strong consumption similarity') follows as $s^r\mathbf{f} = \mathbf{f}^r$. Rewriting the condition can be stated as

$$t_f^r = V^r - s^r\mathbf{b}'\mathbf{f} = V^r - \mathbf{b}'s^r\mathbf{f} = V^r - \mathbf{b}'\mathbf{S}^r\mathbf{f}$$

with $\mathbf{S}^r = s^r\mathbf{I}_{NC}$ with $s^r = \sum_{p,i} f_i^{pr} / \sum_{p,r,i} f_i^{pr}$. This formulation can be used to impose more structure on the consumption patterns. Note, that the weak consumption similarity just imposes homothetic preferences, the strong consumption similarity imposes additionally that a country consumes proportionally from all other countries (as, e.g. in monopolistic competition models with taste for varieties or models with homothetic preferences and complete specialization in production.) Therefore, allowing for country-pair specific trade patterns but - again - homogenous preferences leads to the testable equation

$$t_f^r = V^r - \mathbf{b}'\mathbf{S}^r\mathbf{f}$$

with various specifications of the share matrix $\mathbf{S}^r$.

The above formulation allows one to introduce country specific patterns in the following ways. The assumption of homothetic preferences though still imposing the assumption of proportional consumption across countries. Non-homothetic preferences arise due to differences in income per capita (see Maskus, 1985; Linder, 1961). Second, the assumption of proportional consumption across countries might be violated by the fact that distance, transport costs and other variables such as landlockedness, cultural similarities, tariffs, etc. play an important role in trade flows across countries as documented by the large literature testing gravity models (see Linnemann, 1966, for an early reference). When using the empirical demand shares, i.e. a typical element of the share matrix $\mathbf{S}^r$ becomes $s_i^{pr} = \frac{f_i^{pr}}{\sum_{i,p} f_i^{pr}}$ the HOV condition must hold by definition. Summarizing, we test the cases listed in Table 1. In the 'SCS' case preferences are assumed to be homothetic and sourcing structures (in final demand) are proportional across countries for each industry. This can be relaxed in various ways. Case (1) allows for non-homothetic preferences - i.e. using the actual expenditure shares - but still assumes proportional sourcing structures across countries; Case (2) reverts back to homothetic preferences but uses country level sourcing structures (though these are assumed to be the same across industries). This is relaxed in case (3). Case (4) is then again assuming non-homothetic preferences but country-level sourcing structures of intermediates. When using the actual

Table 1 Overview

Case	Preferences	Sourcing structures
SCS	Homothetic	Proportional
(1)	Non-homothetic	Proportional
(2)	Homothetic	Empirical sourcing at country level
(3)	Homothetic	Empirical sourcing at country-industry level
(4)	Non-homothetic	Empirical sourcing at country level
HOV	Non-homothetic	Empirical sourcing at country-industry level

expenditure shares and actual sourcing structures the HOV has to be satisfied by definition. Behind the relaxations of the preferences and sourcing structures are explanatory factors like per capita income and gravity variables, respectively. Alternatively, one might estimate consumption functions and gravity equations to predict the effects. However, in this framework we use the empirical facts and thus do not go into detail on driving forces behind the differences in consumption shares and sourcing structures. One should also notice that throughout this exercise the sourcing of intermediates corresponds to the actual situation.

3.3. Empirical test of the Vanek prediction

The various empirical tests of the Vanek prediction are outlined e.g. in Trefler and Zhu (2010). Such tests include a sign test, a rank correlation test, and a regression based test which are reported in the following.

3.3.1. Sign and rank correlation test

The sign test calculates the number of cases for which the RHS and LHS have the same sign; i.e. a country abundant in a particular factor - taking into account productivity differences - is expected to be a net exporter of this factor. Results of this simple test are reported in Table 2 for the three ways of modeling goods demand outlined above. The first part of the table shows the usual HOV model when allowing for intermediates trade and technology differences. We can go beyond Trefler and Zhu (2010) by showing this test not only for total employment but also for employment broken down by educational attainment categories and capital. As one can see, the sign test performs rather well with a value greater than 90% over the whole period. The performance of HOV improves over time and is higher since 2000 with all countries often showing the correct sign. The prediction is however less good in the year 2009. Similar conclusions hold for the individual employment categories, though the performance is slightly worse for capital with on average just 75% of correct signs.

Given these already high success rates one cannot expect too much improvement by allowing for non-homothetic preferences and non-proportional consumption structures across countries. Indeed, the performance with non-homothetic preferences is very similar (and maybe slightly worse) whereas the performance when allowing for non-proportional trade structures tends to be slightly improved.

Similarly, the rank correlation test provides highly significant results which are reported in Table 6 with again similar conclusions, i.e. the model performs less good with respect to capital inputs (though results are still highly significant). The Spearman rank correlation coefficients are around 0.95 for the overall endowment measures.[4] Again these results are in line with those reported in Trefler and Zhu (2010) reporting a rank correlation coefficient of 0.89 for employment in their sample. However, the rank correlation becomes smaller in the case of non-proportionality and particularly so for high-educated workers.

[4]Simple correlations yield similar results.

Table 2 Sign test (Number of cases met)

Variable	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Strong consumption similarity															
Employed	37	37	35	36	36	37	39	40	40	40	39	39	39	39	35
.. High	36	35	36	36	37	38	36	36	38	37	38	39	38	38	35
.. Medium	38	38	38	39	37	37	36	37	37	37	38	36	37	36	35
.. Low	38	38	38	39	39	38	40	40	38	39	39	40	40	40	39
Capital	29	30	33	34	33	34	33	34	33	32	34	34	34	34	37
Non-homothetic preferences, proportionality															
Employed	35	36	33	35	36	37	39	39	40	39	38	38	40	40	36
.. High	36	35	36	35	37	38	37	36	38	37	38	39	38	38	35
.. Medium	38	38	37	38	37	37	36	37	37	37	38	37	36	35	35
.. Low	39	38	37	39	38	38	38	38	39	39	39	40	40	40	39
Capital	30	31	34	35	35	35	35	32	35	33	33	33	33	35	38
Homothetic, Non-proportionality at country level															
Employed	36	35	35	35	34	35	38	38	39	39	39	39	37	38	36
.. High	36	34	33	36	34	39	36	34	38	37	36	36	35	36	33
.. Medium	37	37	38	37	37	37	37	37	37	37	36	37	37	40	39
.. Low	39	38	39	38	38	36	39	40	39	38	38	36	37	37	37
Capital	28	28	33	35	33	33	32	36	36	34	37	37	37	36	38
Homothetic, Non-proportionality at country-industry level															
Employed	38	38	36	37	35	37	37	37	36	39	37	39	38	39	38
.. High	28	28	28	31	34	36	33	34	33	33	31	28	31	32	31
.. Medium	38	37	36	36	37	36	36	35	35	35	36	37	37	36	37
.. Low	36	37	38	39	38	38	39	39	38	38	36	36	36	37	37
Capital	29	28	32	36	33	31	34	35	34	37	38	38	38	37	35
Non homothetic, Non-proportionality at country level															
Employed	37	37	35	36	34	35	38	38	40	40	39	39	39	38	35
.. High	35	33	33	37	35	39	37	34	38	38	37	37	36	36	34
.. Medium	37	37	37	37	37	37	38	37	37	37	36	37	38	40	39
.. Low	39	38	39	39	37	38	40	40	39	40	40	39	38	38	38
Capital	27	30	34	35	33	33	34	35	34	34	36	36	35	36	39

Table 3 Rank correlation test (Spearman's rho)

Variable	SCS	Non-homothetic	Non-proportional
Employment	0.955^{***}	0.945^{***}	0.961^{***}
.. High	0.956^{***}	0.956^{***}	0.528^{***}
... Medium	0.956^{***}	0.945^{***}	0.840^{***}
... Low	0.972^{***}	0.940^{***}	0.947^{***}
Capital	0.826^{***}	0.860^{***}	0.819^{***}

3.3.2. Regression analysis

A further test suggested in Trefler and Zhu (2010) involves running a regression of the measured factor content of trade on the predicted one, i.e.

$$\mathrm{FCT}^{measured,r} = \alpha + \beta\,\mathrm{FCT}^{predicted,r} + \varepsilon^r$$

for which a positive slope coefficient on β is expected. Our data allow us to make use of the panel nature of the observations and thus we run a fixed effects regression controlling for country-specific characteristics which are constant over time.[5] This might also account for potential measurement errors. Results are reported in Table 4. Coefficients for all endowment measures are positive and highly significant. The

Table 4 - Slope coefficients (random effects)

	Total sample					Reduced sample				
	Emp.	High	Medium	Low	Capital	Emp.	High	Medium	Low	Capital
	Strong consumption similarity									
FCTp	0.139***	0.136***	0.149***	0.134***	0.108***	0.127***	0.136***	0.142***	0.127***	0.094***
s.e.	0.005	0.004	0.005	0.005	0.003	0.003	0.004	0.003	0.003	0.003
R2	0.920	0.871	0.916	0.920	0.628	0.959	0.871	0.954	0.965	0.362
	Non-homothetic preferences, proportionality									
FCTp	0.179***	0.156***	0.169***	0.186***	0.113***	0.156***	0.156***	0.162***	0.180***	0.100***
s.e.	0.006	0.004	0.006	0.006	0.003	0.004	0.004	0.004	0.004	0.003
R2	0.926	0.860	0.916	0.925	0.726	0.941	0.860	0.946	0.963	0.527
	Homothetic, Non-proportionality at country level									
FCTp	0.053***	0.009***	0.023***	0.115***	0.106***	0.064***	0.009***	0.032***	0.105***	0.110***
s.e.	0.005	0.002	0.003	0.006	0.003	0.003	0.002	0.003	0.005	0.004
R2	0.827	0.577	0.727	0.883	0.665	0.891	0.577	0.818	0.908	0.456
	Homothetic, Non-proportionality at country-industry level									
FCTp	0.569***	0.608***	0.484***	0.234***	0.610***	0.746***	0.608***	0.786***	0.766***	0.616***
s.e.	0.024	0.021	0.013	0.025	0.011	0.012	0.021	0.009	0.010	0.015
R2	0.861	0.476	0.476	0.811	0.815	0.830	0.476	0.979	0.978	0.696
	Non-homothetic, Non-proportionality at country level									
FCTp	0.039***	0.011***	0.015***	0.108***	0.114***	0.048***	0.011***	0.022***	0.083***	0.130***
s.e.	0.004	0.002	0.003	0.006	0.003	0.003	0.002	0.002	0.004	0.005
R2	0.786	0.601	0.681	0.875	0.757	0.873	0.601	0.795	0.886	0.670

magnitude of the slope coefficients in the model with strong consumption similarity at around 0.14 are however somewhat smaller than those reported in Trefler and Zhu (2010) where a figure of 0.32 is reported. The fit of the regressions are rather high with the overall R^2 being between 0.9 with the exception of capital where the R^2 drops to 0.63.

But as in other contributions there is a considerable amount of missing trade ranging between 85 and 90%. Therefore in the second part of the table we allow for non-homothetic preferences which slightly improves the performance of the model, with coefficients that are somewhat higher though still far below one. The most significant increases are found for total employment (from 0.139 to 0.179) and low educated

[5]Additional results are similar and reported in the appendix.

employment(from 0.134 to 0.186). The explained variance is rather similar to the first set of results. The third part of the table provides the result when imposing homothetic preferences but allowing for non-proportional trading structures. This improves the results significantly. The coefficients for total and high educated employment increase to 0.569 and 0.608, respectively, thus leaving only about 40% of missing trade. A similarly strong increase is found for capital, which increases to 0.610. The increase is less significant for medium educated workers (0.484) and there is almost no significant improvement for low educated workers (0.234).

4. Accounting for consumption in bilateral HOV tests

Hakura (2001) provides a way to test the HOV theorem in a bilateral way derived from the global general equilibrium.[6] More recently Cassing and Nishioka (2010) suggest a bilateral test of the HOV allowing for non-homothetic preferences by including a vector for differences in consumption patterns.

4.1. Bilateral HOV test allowing for heterogenous consumption

In this section we generalize the test proposed by Hakura (2001) allowing for traded intermediates as in Trefler and Zhu (2010) and again including the various forms of consumption patterns. The testable equation is as above given by

$$\mathbf{b}\mathbf{t}^r = V^r - \mathbf{b}s^r\mathbf{f}$$

where $\mathbf{b}$ denotes a row (of dimension 1×1435) in matrix $\mathbf{B}$. (We shows this for one particular factor.) Using the standard assumption $\hat{\mathbf{f}}^c \equiv s^c\mathbf{f}$ (where $\hat{\mathbf{f}}^c$ is the predicted consumption vector) it follows that for a particular country $\frac{1}{s^c}\hat{\mathbf{f}}^c = \mathbf{f}$. This establishes a relation between consumption vectors for two countries as

$$\hat{\mathbf{f}}^c = \frac{s^c}{s^r}\hat{\mathbf{f}}^r.$$

Thus, the testable equation for the second country can be written as

$$\mathbf{b}\mathbf{t}^c = V^c - \mathbf{b}s^c\mathbf{f} = V^c - \mathbf{b}\hat{\mathbf{f}}^c = V^c - \mathbf{b}\frac{s^c}{s^r}\hat{\mathbf{f}}^r$$

Subtracting this equation from the one for country c yields

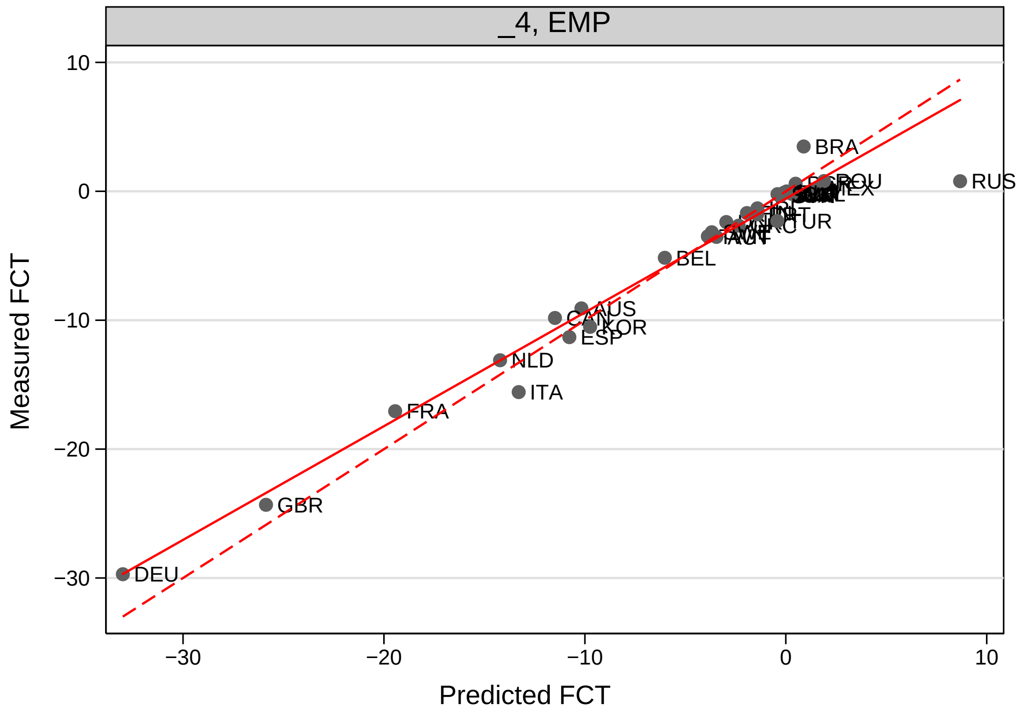
$$\mathbf{b}\mathbf{t}^r - \mathbf{b}\mathbf{t}^c = V^r - \mathbf{b}\hat{\mathbf{f}}^r - (V^c - \mathbf{b}\frac{s^c}{s^r}\mathbf{f}^r) = (V^r - V^c) + (\mathbf{b}\frac{s^c}{s^r}\hat{\mathbf{f}}^r - \mathbf{b}\hat{\mathbf{f}}^r)$$

which can be simplified to

$$\mathbf{b}(\mathbf{t}^r - \mathbf{t}^c) = (V^r - V^c) + \mathbf{b}(\frac{s^c}{s^r} - 1)\hat{\mathbf{f}}^r = (V^r - V^c) + \mathbf{b}(\frac{s^c}{s^r} - 1)s^r\mathbf{f} = (V^r - V^c) + \mathbf{b}(s^c - s^r)\mathbf{f}$$

For two countries with equal factor endowment structures and sizes the difference is expected to be zero. Two countries with the same endowment structures but different sizes would only differ by a scalar ($s^c -$

[6]It should be noted that this is different from a bilateral test of the HOV theorem. See Foster and Stehrer (2012) for a paper based on the WIOD data.



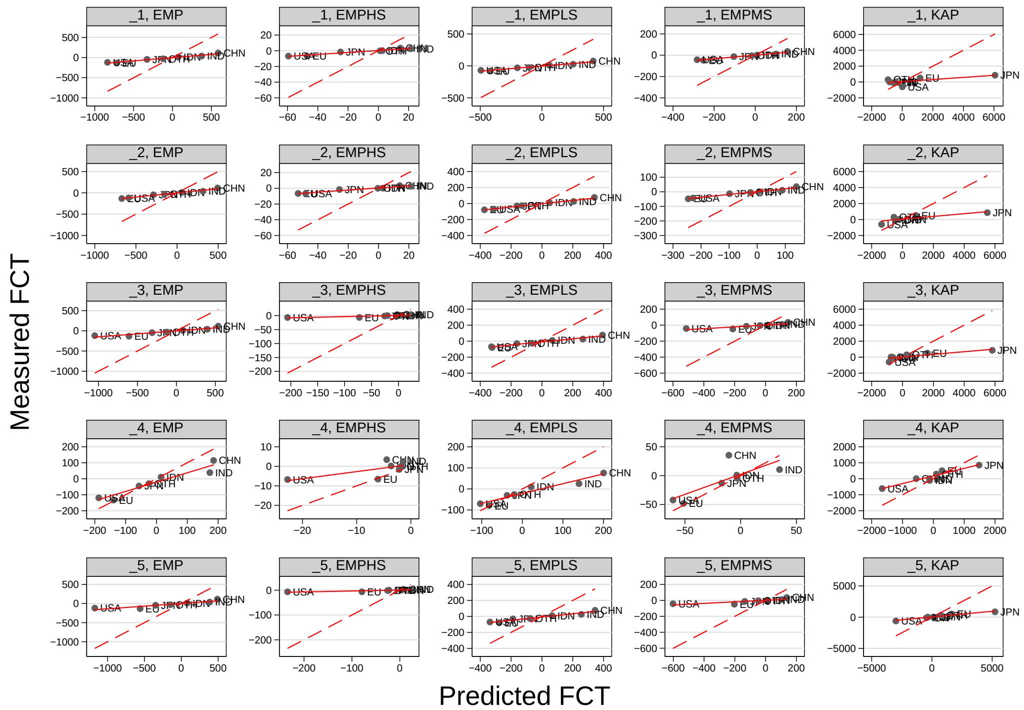


Figure 1. Measured versus predicted FCT

s^r). This can be generalized as before by rewriting these equations in matrix notation starting with $\hat{\mathbf{f}}^c = \mathbf{S}^c(\mathbf{S}^r)^{-1}\hat{\mathbf{f}}^r$. Using the same steps as above provides

$$\begin{aligned}\mathbf{b}(\mathbf{t}^r - \mathbf{t}^c) &= (V^r - V^c) + \mathbf{b}\Big(\mathbf{S}^c(\mathbf{S}^r)^{-1} - \mathbf{I}\Big)\mathbf{f}^r \\ &= (V^r - V^c) + \mathbf{b}\Big(\mathbf{S}^c(\mathbf{S}^r)^{-1} - \mathbf{I}\Big)\mathbf{S}^r\mathbf{f} \\ &= (V^r - V^c) + \mathbf{b}\Big(\mathbf{S}^c - \mathbf{S}^r\Big)\mathbf{f}\end{aligned}$$

with a similar - however more complex - interpretation as above. The more complex interpretation arises from the fact that it is no longer a difference in the scalar which matters but a difference in the diagonal matrices $\mathbf{S}^p$.

This exposition allows, exactly as above, to test restrictions on preferences (homothetic versus non-homothetic) and the proportionality of consumption across countries which can be tested by using the respective definitions of $\mathbf{S}^p$.

4.2. Bilateral tests of the Vanek prediction

In this section we present the statistics for the bilateral HOV model. Overall, the results are very similar to the ones presented above.

4.2.1. Sign and rank correlation test

The sign test calculates the number of cases for which the RHS and LHS have the same sign; i.e. a country abundant in a particular factor - taking into account productivity differences - is expected to be a net exporter of this factor. Results of this simple test are reported in Table 2.

4.2.2. Regression analysis

... TEXT TO BE INCLUDED ...

Table 5 Sign test (Number of cases met)

Variable	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Strong consumption similarity															
Employed	94.0	93.7	93.1	92.1	93.8	93.5	94.4	95.4	94.5	96.2	94.7	95.0	94.4	93.7	92.6
.. High	90.3	90.4	89.9	91.8	92.3	94.1	92.1	92.7	94.4	93.8	93.8	94.2	92.4	92.1	92.9
.. Medium	93.3	93.5	93.5	94.1	93.7	94.5	93.3	94.7	95.3	95.8	95.3	95.4	94.2	92.6	95.8
.. Low	95.0	94.5	94.0	94.9	94.6	92.7	95.6	95.6	95.0	96.4	96.4	96.8	96.8	97.2	96.0
Capital	80.9	77.7	81.2	82.7	83.7	83.8	84.1	84.4	85.4	85.0	85.1	86.5	85.5	89.2	93.3
Non-homothetic preferences, proportionality															
Employed	91.4	91.9	90.6	89.6	92.3	92.7	94.1	94.4	93.5	93.5	92.1	92.6	93.2	94.5	90.5
.. High	90.6	90.3	90.3	92.3	92.8	94.1	92.3	92.8	94.1	93.8	93.7	93.7	91.9	92.2	92.8
.. Medium	92.9	93.3	93.2	94.1	93.6	93.8	92.8	93.7	95.3	93.6	93.7	93.3	93.2	92.1	94.7
.. Low	93.1	91.9	89.5	90.4	91.4	92.3	93.3	92.4	93.1	93.8	93.8	93.3	95.5	95.0	92.4
Capital	81.8	81.5	85.1	85.8	87.3	87.7	87.2	85.5	86.4	86.3	85.0	86.4	87.2	91.7	94.9
Homothetic, Non-proportionality at country level															
Employed	92.3	93.1	91.4	90.6	91.0	92.4	93.1	93.2	92.8	95.3	93.3	93.7	91.0	90.8	92.2
.. High	86.3	86.9	85.1	85.4	84.5	89.0	83.7	83.7	91.3	86.9	85.0	86.8	86.8	83.8	84.4
.. Medium	90.8	91.2	91.7	91.8	91.2	92.1	93.1	93.1	94.2	93.8	94.5	94.7	95.1	94.6	95.0
.. Low	91.8	92.1	93.3	91.3	91.5	88.5	92.2	92.3	91.9	91.4	89.0	89.0	89.1	89.4	91.3
Capital	70.8	70.4	79.2	82.4	83.6	81.9	83.5	86.5	87.4	86.9	87.4	88.8	88.7	89.0	88.8
Homothetic, Non-proportionality at country-industry level															
Employed	94.1	94.2	93.3	95.6	92.9	94.1	93.3	93.8	95.1	94.9	93.7	94.5	93.3	95.5	94.0
.. High	68.7	65.9	66.0	70.8	74.9	79.4	76.4	76.5	76.3	77.6	77.4	75.3	75.5	75.9	71.3
.. Medium	89.5	87.7	87.9	87.6	87.2	90.0	89.4	88.3	90.0	89.4	92.9	93.3	93.6	91.2	92.1
.. Low	92.8	92.9	92.8	94.9	94.2	93.2	95.1	95.6	95.0	94.1	92.6	92.8	91.5	91.8	93.8
Capital	76.8	73.7	75.0	82.2	84.4	83.7	85.0	84.7	86.3	89.6	89.0	89.9	90.9	89.7	86.9
Non homothetic, Non-proportionality at country level															
Employed	92.1	92.6	91.8	90.4	89.5	90.3	92.3	92.9	93.6	96.0	92.7	92.7	91.5	90.5	91.4
.. High	85.5	85.5	84.6	89.0	87.6	90.0	86.5	87.2	92.1	90.4	88.5	87.6	87.1	86.8	88.3
.. Medium	90.3	90.4	91.3	91.3	90.4	92.1	92.3	93.5	94.0	93.8	94.5	94.6	94.5	94.1	94.7
.. Low	92.2	92.2	92.4	88.2	89.6	88.7	92.1	92.4	92.3	94.4	91.2	91.2	90.3	90.9	92.3
Capital	72.2	75.1	82.8	85.1	86.4	85.8	86.0	88.5	88.2	88.3	87.2	88.7	89.0	92.4	89.0

Table 6 Rank correlation test (Spearman's rho)

Variable	SCS	Non-homothetic	Non-proportional
Employment	0.971^{***}	0.966^{***}	0.980^{***}
.. High	0.951^{***}	0.950^{***}	0.417^{***}
... Medium	0.971^{***}	0.967^{***}	0.806^{***}
... Low	0.981^{***}	0.966^{***}	0.972^{***}
Capital	0.851^{***}	0.887^{***}	0.799^{***}

Table 7 - Slope coefficients (random effects)

	Total sample					Reduced sample				
	Emp.	High	Medium	Low	Capital	Emp.	High	Medium	Low	Capital
	Strong consumption similarity									
FCTp	0.139***	0.137***	0.150***	0.135***	0.107***	0.128***	0.137***	0.142***	0.128***	0.102***
s.e.	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000
R2	0.921	0.872	0.917	0.920	0.628	0.960	0.872	0.957	0.967	0.528
	Non-homothetic preferences, proportionality									
FCTp	0.180***	0.157***	0.170***	0.186***	0.113***	0.158***	0.157***	0.163***	0.182***	0.107***
s.e.	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001
R2	0.926	0.861	0.917	0.926	0.726	0.943	0.861	0.949	0.966	0.652
	Homothetic, Non-proportionality at country level									
FCTp	0.055***	0.009***	0.024***	0.118***	0.108***	0.067***	0.009***	0.034***	0.111***	0.108***
s.e.	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.001
R2	0.829	0.577	0.730	0.884	0.670	0.898	0.577	0.826	0.917	0.593
	Homothetic, Non-proportionality at country-industry level									
FCTp	0.572***	0.612***	0.486***	0.244***	0.612***	0.744***	0.612***	0.781***	0.762***	0.614***
s.e.	0.004	0.003	0.002	0.004	0.002	0.002	0.003	0.001	0.002	0.002
R2	0.862	0.476	0.477	0.812	0.817	0.831	0.476	0.980	0.978	0.772
	Non-homothetic, Non-proportionality at country level									
FCTp	0.040***	0.011***	0.015***	0.112***	0.115***	0.051***	0.011***	0.024***	0.089***	0.119***
s.e.	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.001
R2	0.789	0.602	0.683	0.877	0.764	0.880	0.602	0.804	0.897	0.728

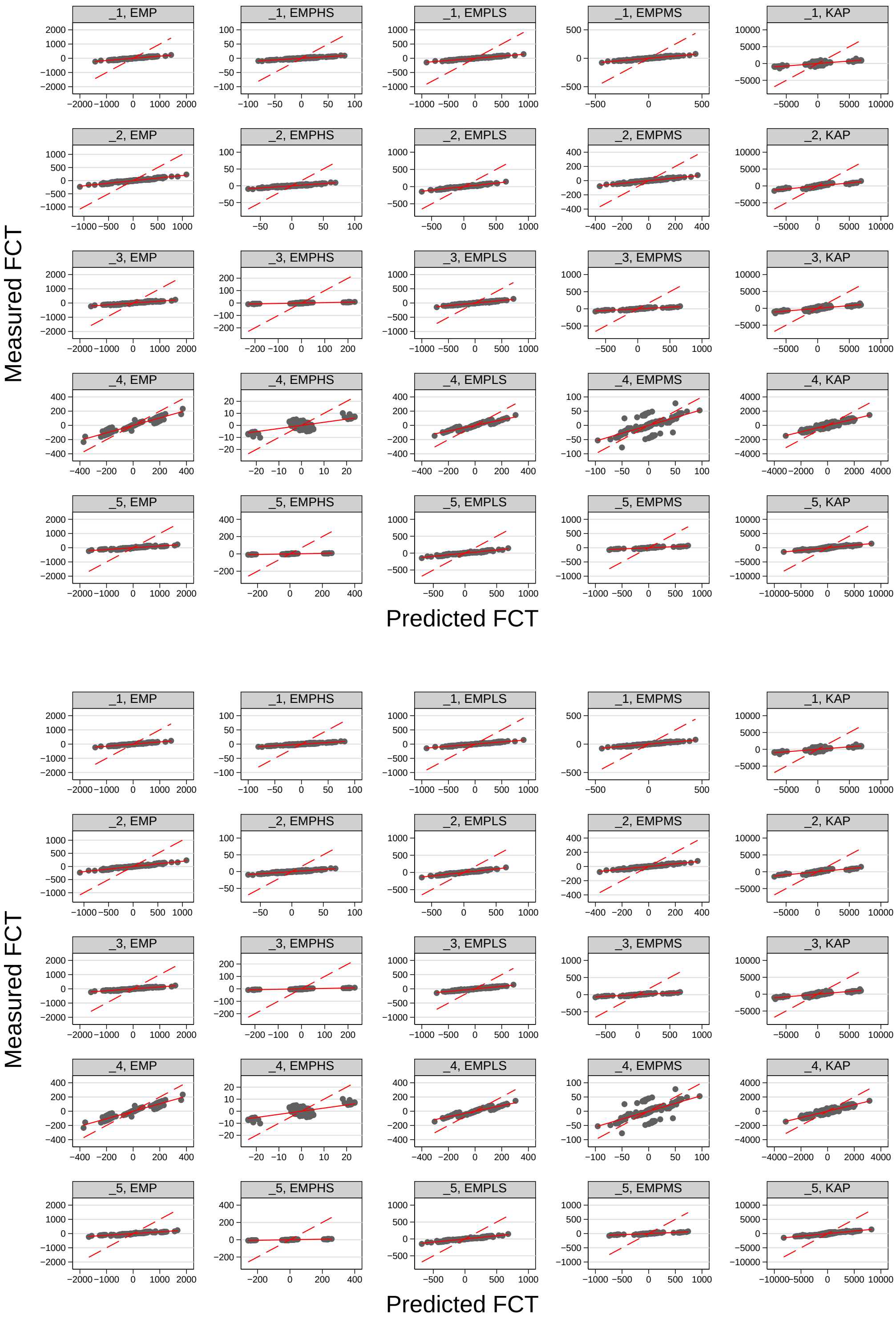


Figure 2. Measured versus predicted FCT

5. Summary and conclusions

... TO BE COMPLETED ...

AppendixA. Additional tables: Total

Table 8 - Slope coefficients - OLS

	Total sample					Reduced sample				
	Total	High	Medium	Low	Capital	Total	High	Medium	Low	Capital
	Strong consumption similarity									
FCTp	0.152***	0.117***	0.160***	0.151***	0.126***	0.136***	0.117***	0.147***	0.143***	0.108***
s.e.	0.002	0.002	0.002	0.002	0.004	0.001	0.002	0.001	0.001	0.006
r2	0.920	0.871	0.916	0.920	0.628	0.959	0.871	0.954	0.965	0.362
	Non-homothetic preferences, proportionality									
FCTp	0.195***	0.131***	0.187***	0.204***	0.142***	0.178***	0.131***	0.176***	0.214***	0.133***
s.e.	0.002	0.002	0.002	0.002	0.004	0.002	0.002	0.002	0.002	0.005
r2	0.926	0.860	0.916	0.925	0.726	0.941	0.860	0.946	0.963	0.527
	Homothetic, Non-proportionality at country level									
FCTp	0.126***	0.033***	0.090***	0.174***	0.132***	0.108***	0.033***	0.076***	0.189***	0.141***
s.e.	0.002	0.001	0.002	0.003	0.004	0.002	0.001	0.002	0.003	0.006
r2	0.827	0.577	0.727	0.883	0.665	0.891	0.577	0.818	0.908	0.456
	Homothetic, Non-proportionality at country-industry level									
FCTp	0.527***	0.272***	0.545***	0.389***	0.491***	0.472***	0.272***	0.711***	0.685***	0.441***
s.e.	0.009	0.012	0.023	0.008	0.010	0.009	0.012	0.004	0.004	0.012
r2	0.861	0.476	0.476	0.811	0.815	0.830	0.476	0.979	0.978	0.696
	Non-homothetic, Non-proportionality at country level									
FCTp	0.115***	0.029***	0.076***	0.180***	0.143***	0.097***	0.029***	0.065***	0.180***	0.164***
s.e.	0.002	0.001	0.002	0.003	0.003	0.002	0.001	0.001	0.003	0.005
r2	0.786	0.601	0.681	0.875	0.757	0.873	0.601	0.795	0.886	0.670

Table 9 - Slope coefficients - Fixed effects

	Total sample					Reduced sample				
	Total	High	Medium	Low	Capital	Total	High	Medium	Low	Capital
	Strong consumption similarity									
FCTp	0.082***	0.158***	0.127***	0.036***	0.107***	0.102***	0.158***	0.122***	0.084***	0.093***
s.e.	0.010	0.005	0.008	0.011	0.003	0.005	0.005	0.006	0.005	0.003
R2	0.920	0.871	0.916	0.920	0.628	0.959	0.871	0.954	0.965	0.362
	Non-homothetic preferences, proportionality									
FCTp	0.120***	0.174***	0.134***	0.085***	0.110***	0.129***	0.174***	0.130***	0.120***	0.097***
s.e.	0.012	0.006	0.009	0.014	0.003	0.006	0.006	0.007	0.006	0.003
R2	0.926	0.860	0.916	0.925	0.726	0.941	0.860	0.946	0.963	0.527
	Homothetic, Non-proportionality at country level									
FCTp	0.011	-0.008***	0.009***	0.014	0.104***	0.017***	-0.008***	0.007***	0.042***	0.109***
s.e.	0.005	0.003	0.003	0.009	0.003	0.003	0.003	0.002	0.004	0.004
R2	0.827	0.577	0.727	0.883	0.665	0.891	0.577	0.818	0.908	0.456
	Homothetic, Non-proportionality at country-industry level									
FCTp	0.639***	0.696***	0.482***	-0.204***	0.627***	0.777***	0.696***	0.822***	0.806***	0.647***
s.e.	0.039	0.022	0.013	0.043	0.011	0.012	0.022	0.010	0.011	0.015
R2	0.861	0.476	0.476	0.811	0.815	0.830	0.476	0.979	0.978	0.696
	Non-homothetic, Non-proportionality at country level									
FCTp	0.013***	-0.006	0.005	0.036***	0.106***	0.012***	-0.006	0.003	0.034***	0.122***
s.e.	0.004	0.003	0.003	0.007	0.003	0.003	0.003	0.002	0.004	0.005
R2	0.786	0.601	0.681	0.875	0.757	0.873	0.601	0.795	0.886	0.670

AppendixB. Additional tables: Bilateral

Table 10 - Slope coefficients - OLS

	Total sample					Reduced sample				
	Emp.	High	Medium	Low	Capital	Emp.	High	Medium	Low	Capital
	Strong consumption similarity									
FCTp	0.152***	0.117***	0.160***	0.151***	0.126***	0.136***	0.117***	0.147***	0.143***	0.120***
s.e.	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
r2	0.921	0.872	0.917	0.920	0.628	0.960	0.872	0.957	0.967	0.528
	Non-homothetic preferences, proportionality									
FCTp	0.195***	0.131***	0.187***	0.204***	0.142***	0.178***	0.131***	0.176***	0.214***	0.139***
s.e.	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
r2	0.926	0.861	0.917	0.926	0.726	0.943	0.861	0.949	0.966	0.652
	Homothetic, Non-proportionality at country level									
FCTp	0.126***	0.033***	0.090***	0.175***	0.132***	0.108***	0.033***	0.077***	0.190***	0.135***
s.e.	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
r2	0.829	0.577	0.730	0.884	0.670	0.898	0.577	0.826	0.917	0.593
	Homothetic, Non-proportionality at country-industry level									
FCTp	0.527***	0.272***	0.546***	0.389***	0.492***	0.472***	0.272***	0.710***	0.685***	0.473***
s.e.	0.001	0.002	0.004	0.001	0.002	0.001	0.002	0.001	0.001	0.002
r2	0.862	0.476	0.477	0.812	0.817	0.831	0.476	0.980	0.978	0.772
	Non-homothetic, Non-proportionality at country level									
FCTp	0.115***	0.030***	0.076***	0.181***	0.143***	0.098***	0.030***	0.065***	0.182***	0.149***
s.e.	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
r2	0.789	0.602	0.683	0.877	0.764	0.880	0.602	0.804	0.897	0.728

Table 11 - Slope coefficients - FE

	Total sample					Reduced sample				
	Emp.	High	Medium	Low	Capital	Emp.	High	Medium	Low	Capital
					Strong consumption similarity					
FCTp	0.081***	0.159***	0.127***	0.033***	0.106***	0.106***	0.159***	0.125***	0.088***	0.101***
s.e.	0.002	0.001	0.001	0.002	0.000	0.001	0.001	0.001	0.001	0.000
R2	0.921	0.872	0.917	0.920	0.628	0.960	0.872	0.957	0.967	0.528
					Non-homothetic preferences, proportionality					
FCTp	0.119***	0.177***	0.135***	0.082***	0.110***	0.135***	0.177***	0.133***	0.127***	0.105***
s.e.	0.002	0.001	0.002	0.002	0.000	0.001	0.001	0.001	0.001	0.000
R2	0.926	0.861	0.917	0.926	0.726	0.943	0.861	0.949	0.966	0.652
					Homothetic, Non-proportionality at country level					
FCTp	0.009***	-0.009***	0.008***	0.009***	0.105***	0.019***	-0.009***	0.008***	0.048***	0.106***
s.e.	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
R2	0.829	0.577	0.730	0.884	0.670	0.898	0.577	0.826	0.917	0.593
					Homothetic, Non-proportionality at country-industry level					
FCTp	0.647***	0.704***	0.485***	-0.195***	0.629***	0.775***	0.704***	0.816***	0.802***	0.636***
s.e.	0.006	0.003	0.002	0.007	0.002	0.002	0.003	0.002	0.002	0.002
R2	0.862	0.476	0.477	0.812	0.817	0.831	0.476	0.980	0.978	0.772
					Non-homothetic, Non-proportionality at country level					
FCTp	0.012***	-0.006***	0.004***	0.033***	0.107***	0.014***	-0.006***	0.004***	0.040***	0.111***
s.e.	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.001
R2	0.789	0.602	0.683	0.877	0.764	0.880	0.602	0.804	0.897	0.728

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