Convergence or Divergence of Production Patterns in the EU: Empirical Test of the Multiple-Cone Heckscher-Ohlin Model

KENSUKE SUZUKI*

This paper examines whether countries exhibit convergence or divergence in production patterns over time. I employ the production side of the Heckscher-Ohlin model as a theoretical framework. Using data on countries endowments and sectoral output for the 22 European Union member states from 1995 to 2006, I estimate development path for the single- and multiple-cone model year-by-year. The results reveal evidence for the multiple-cone equilibrium for the 2000s, but not for the 1990s. It suggest that diversity in production patterns in the EU become more evident. Trade liberalization between capital- and labor-abundant countries may have enhanced the international division of labor in accordance with countries' comparative advantage.

JEL: F11, F14, F6,

Keywords: Hekchscer-Ohlin model, Production pattern, European Union

I. Introduction

This paper attempts to examine empirically whether countries exhibit convergence or divergence in production patterns over time. I employ the production side of the Heckscher-Ohlin (HO) model as a theoretical framework. In particular, this paper focuses on the two types of equilibrium that can arise within the HO framework; single- and multiple-cone equilibrium.[1] The single-cone equilibrium has all countries in the world producing all goods. On the other hand, in the multiple-cone equilibrium, countries specialize in the distinct subsets of goods according to their relative factor endowments. Thus, if an economy maintains the multiple-cone equilibrium over time, it suggests that there exists persistent variation in production patterns across countries. Alternatively, shift from one to the other equilibrium can be also occurred. In case of shift from multiple- to single-cone equilibrium, for example, it implies convergence in production patterns,

* Graduate School of Economics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, AICHI 464-8601, Japan, and the Japan Society for the Promotion of Science (JSPS). I thank JSPS KAKENHI Grant Number JP15J01682 for research support.

[1] Cone refers to "a set of factor endowment combinations that are consistent with producing the same set of goods and having the same factor prices" (Deardorff, 2014).

and *vice versa*. Since the HO model is fundamentally built on the static framework, an equilibrium is characterized by prevailing goods prices and production technologies at each point in time. Consequently, changes in these parameters may alter the equilibrium condition and the structure of cones as well. Moreover, those changes are likely to be triggered by, for example, trade liberalization and broader economic integration. Thus, determining whether the multiple- or single-cone equilibrium remains over time is important factor to gauge an effect of globalization on production patterns.

In this paper, I estimate the relationship between countrywide capital–labor ratio and per capita sectoral output, i.e., development path *a là* Leamer (1987) for the single- and multiple-cone equilibrium. I make use of data on factor endowments and sectoral output of manufacturing industries for the 22 European Union (EU) member states. By adopting a empirical method introduced by Schott (2003), this paper performs year-by-year estimation of development path from 1995 to 2006. By testing the single-cone model against alternative multiple-cone model, I examine whether the structure of cone remains over the sampled period.

This paper's sampled countries and years are relevant for my analysis from the following perspectives. Firstly, the EU is a free trade area and likely to satisfy a fundamental assumption of the factor proportions framework. Secondly, there is diversity in relative factor endowments that is important for identifying specialization. The sample includes the new member states that joined the EU in 2004 and 2007.[2] These countries, usually labeled as the Central and Eastern European countries (CEECs), are known to be relatively labor-abundant *vis-à-vis* the original member states. Thirdly, the dataset covers the period when the new member states are increasingly involved in the European single market. Prior to their accession to the EU, tariffs on trade in manufactured products between the CEECs and the EU have been abolished by 2002 due to the Europe Agreement. These trade reform may alter the equilibrium conditions of the EU manufacturing production and thus affect the structure of cones.[3]

In testing the production implication of the HO model, a number of studies has examined a linear Rybczynski relationship between countries' factor endowments and sectoral outputs. Harrigan (1995) performs the first empirical examination of the production side of the HO model using data on manufacturing output and factor endowments for

[2]In this paper, the new member states refers to the countries that joined the EU in the 2004 and 2007 enlargement. The member states prior to 2004 (EU-15) is labeled as the original member states.

[3]Large number of literature document the significant effect of the new member states on EU industry, e.g., Crespo and Fontoura (2007) and European Commission (2007).

OECD countries. Following studies including Harrigan (1997), Bernstein and Weinstein (2002), and Redding (2002) have attempted to find the empirical validity of the model by making modifications on treatment on technological differences, sampled countries (regions), econometric specification, and so forth. Although these studies confirm the significant role of factor endowments in explaining production patterns across countries, they also reveal the weak explanatory power of the model.

Regarding this issue, Schott (2003) argue that the existing literature has focused on the overly restrictive single-cone assumption and the alternative multiple-cone model needs to be considered.[4] In the multiple-cone model, countries with sufficiently disparate endowments inhabit different cones and specialize in distinct subsets of goods. Moreover, factor prices are equalized across countries within the same cone, but not in different cones. Consequently, the Stolper-Samuelson effect is dampened, or broken, across countries in the different cones.[5] Schott argues that empirical analysis with multiple-cone equilibrium may provide richer implication for considering the determinant of production patterns as well as response of wages to globalization. By using a cross-country data for 45 countries, he finds a strong support for the HO specialization in favor of the two-cone equilibrium.[6] Other studies also finds the evidence for multiple cones with different empirical approaches. For example, Debaere and Demiroglu (2003) focus on the lens condition of Deardorff (1994) and find that there is more than one cone for the world as a whole. Xiang (2007), on the other hand, confirms the multiple-cone equilibrium by performing bilateral comparisons of the cumulative distribution functions of factor intensity for 10 OECD countries. This paper's questions is how the structure of cones changes along with trade liberalization and economic integration in the EU. By adopting Schott's empirical method, I test single- versus multiple-cone model year-by-year.

There are several related studies that are worth mentioning. Regarding the change in Rybczynski relationship over time, Harrigan (1995) employs a time-varying parameter model in which the coefficients are assume to follow a random walk. He finds that the degree of time variation varies substantially across productive factors and industrious. Batista and Potin (2014), on the other hand, place an emphasis on the cone and analyze the dynamics of industrial specialization. By using the panel of 44 developed and de-

[4]Leamer (1987) also highlights the existence of multiple cones in analyzing the development paths of countries with disparate factor endowments. Furthermore, Leamer and Levinsohn (1995) address importance and difficulty in applying the multiple-cone equilibrium in empirics. They argue that the multiple-cone model needs to be explicitly considered when dataset contains developed and developing countries.

[5]See Davis (1996) for the detailed discussion on the Stolper-Samuelson effects in the multiple-cone world.

[6]By adopting Schott's technique, Kiyota (2011, 2012) finds that the multiple-cone model fits better for Japanese regional data.

veloping countries over 1976–2000, and adopting Schott's (2003) aggregation technique for correcting industry-level data, they estimate the development path of the single-cone model. Although their econometric specification allows capital–labor ratio cutoffs delineating the cone and Rybczynski derivatives to vary over time, their result reveals little changes in these parameters. They concluded that the Rybczynski effect dominates over other effects such as price or technological change in explaining dynamics of production patterns. However, their analysis is exclusively based on the single-cone model and does not examine change in the number of cones. When the number of cones are allowed to vary over time, number of industry aggregates also vary correspondingly in order to preserve evenness.[7] Thus, this paper employs year-by-year estimation of the single- and multiple-cone model instead of time-varying parameter model.[8]

This paper's is also related to the studies on changing degree of specialization over time. As for the European studies, Amiti (1999) analyzes whether specialization has increased in the six EU member states during the process of dismantling trade barriers. She finds divergence in production patterns between 1968 and 1990. While Amiti's work is based on the industry level data that ignore the intra-industry product heterogeneity, this paper attempts to find the evidence for converging or diverging production patterns by taking into account the difference in capital intensity of goods produced by each country. Furthermore, since the HO model is built on the general equilibrium framework, this paper is also related to the literature on income disparity across countries.[9] Regarding this topic, Ben-David (1993) finds that the six original members of the European Economic Community exhibits the convergence of incomes during the period of trade liberalization.

The rest of this paper proceeds as follows: Section II outlines the framework of single- and multiple-cone HO model and derives industry development paths in the respective equilibria; Section III describes data and estimation strategy and present results of year-by-year estimation; and Section IV concludes.

[7]Evenness refers the equilibrium where the number of goods produced by a country is equal to the number of productive factors. Detailed explanation is provided in the next section.

[8]Martincus and Wu (2005) examine whether economic integration in the EU favors countries convergence into a common cone of diversification by employing year-by-year threshold estimation of Rybczynski relationships. Although their motivation is akin to this paper, they rely on industry level data that ignores within-industry product heterogeneity across countries. This paper puts emphasis on variation in capital intensity across countries and years within an industry.

[9]In analyzing the convergence and divergence of income across countries within the HO framework, Deardorff (2001) points out that the multiple-cone equilibrium equipped with multiple steady states can illustrates the polarization of global economies into rich and poor nation. On the other hand, he mentions that in the single-cone model, countries are to reach to the similar income level as they move to the single steady state.

II. Theory

A. Single- and Multiple-Cone Equilibrium

This paper focuses on the production side of the HO model. Although this model is frequently referred in analyzing patterns of trade, it is fundamentally a model of production as Davis et al. (1997) and Reeve (2006) argue. The production implication of the HO model says that there is a linear Rybczynski relationship between country's factor endowments and sectoral output. More specifically, this paper focuses on the relationship between countrywide capital–labor ratio and sectoral per capita output, the development path. This section outlines the structure of the single- and multiple-cone model and derives the development paths of the respective models.

Regarding the model setup, this paper follows Schott (2003) and imposes following assumptions; (1) productive factors are perfectly mobile across sectors within a country, but immobile internationally, (2) countries are small, open, and posses perfectly competitive markets, (3) countries share identical, constant return to scale technology. In order to preclude the complete specialization and reduce the number of parameters to be estimated, I assume that each sector has the Leontief following Schott (2003). I also assume that (4) there is an equal number of factors and goods in each cone in order to avoid the indeterminacy of outputs (i.e., evenness is present).

Suppose that there are two productive factors (capital K and labor L). In the single-cone equilibrium, there is two goods (good 1 and 2). Leontief technology makes each sector's factor input ratio independent from goods prices. The capital intensities of the two sectors are assumed to satisfy $k_1 < k_2$. Following previous works including Schott (2003) and Kiyota (2012), we assume $k_1 = 0$. Panel A of Figure 1 demonstrates the Lerner-Peace diagram of the two-good, single-cone equilibrium. As figure demonstrates, two industries' capital intensities delineate the cone, denoted by $\tau_0 = k_1$ and $\tau_1 = k_2$. A pair of factor prices (r, w) defines the downward-sloping isocost curves for this economy. In the single-cone equilibrium, two sectors' right-angled unit-value isoquants are tangent to the single isocost curve.

Let the countrywide capital–labor ratio of country c be $\overline{k}_c = \overline{K}_c/\overline{L}_c$. If all countries' endowments vectors reside in the single cone of diversification, i.e., $\overline{k}_c \in (\tau_0, \tau_1)$ for $\forall c$, they produce both good 1 and 2 and the factor price equalization (FPE) exhibits globally. Furthermore, sectoral output divided by the total labor endowment $q_i \equiv Q_i/\overline{L}$ (for $i = 1, 2$) is a simple linear function of capital–labor ratio. It implies that there

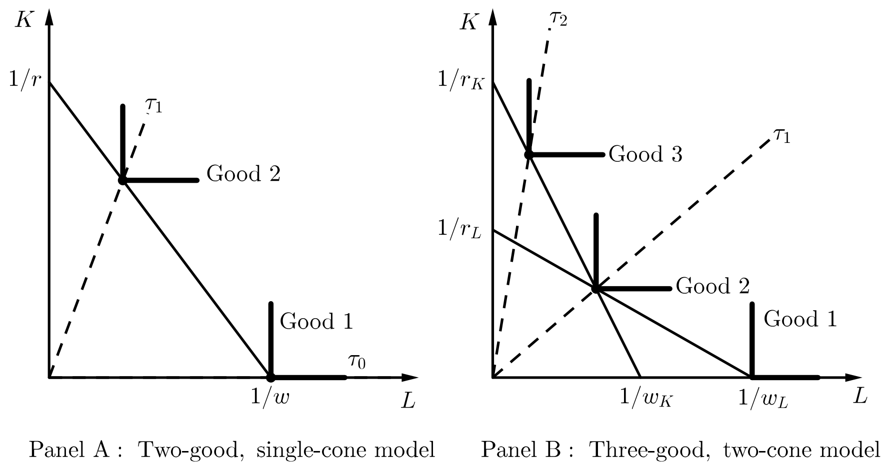


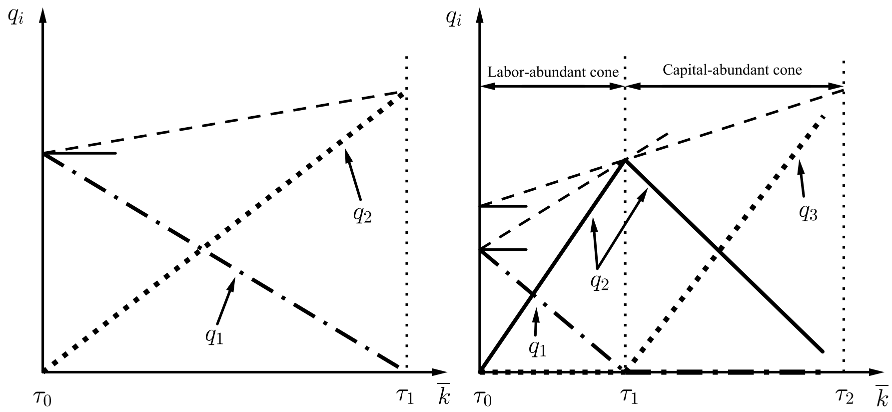
FIGURE 1. LERNER-PEARCE DIAGRAM OF THE SINGLE- AND MULTIPLE-CONE EQUILIBRIUM

exists a one-size-fits all general equilibrium link between factor endowments and sectoral output. Development path of good 1 (2) is monotonically decreasing (increasing) in capital–labor ratio. Industry development path of the single-cone model is demonstrated in the Panel A of Figure 2.

The multiple-cone equilibrium, on the other hand, has diversity in production patterns and the Rybczynski derivatives varies across cones. In order to facilitate discussion, I demonstrate the two-cone model with three goods (good 1, 2, and 3). We assume that good 1 is most labor-intensive, good 3 is most capital-intensive, and good 2 is intermediate capital-intensive good, i.e., $k_1 < k_2 < k_3$. Capital–labor ratio delineating the two cones are denoted by $\tau_{i-1} = k_i$ for $i = 1, 2, 3$ and I assume $\tau_0 = 0$ as well.

Panel B of Figure 2 illustrates the Lerner-Pearce diagram of two-factor, three-good world. Two sets of factor prices, (r_L, w_L) and (r_K, w_K), define the isocost curves for labor- and capital-abundant cone respectively. Intercepts of the isocost curves indicate the reciprocal of the factor prices, suggesting $r_L > r_K$ and $w_K > w_L$. The economy exhibits multiple-cone equilibrium only if technologies and goods prices are such that the isoquants of good 1 and 2 and the those of good 2 and 3 are tangent to the isocost curves denoted (r_L, w_L) and (r_K, w_K) respectively. The location of each isoquant depends on both goods prices and production technology. Thus, if the goods prices and production technologies make three sector' isoquants tangent to the single isocost curve, the economy exhibits the single-cone equilibrium.[10]

[10]If three industries' isoquants are tangent to the single isocost curve, the assumption of evenness is violated



Panel A : Two-good, single-cone model Panel B : Three-good, two-cone model

FIGURE 2. THEORETICAL ARCHETYPE OF INDUSTRY DEVELOPMENT PATH

In the two-cone equilibrium, GDP-maximizing countries specialize in only the two of three industries. Countries in the labor-abundant cone, $\overline{k}_c \in (\tau_0, \tau_1)$, produce good 1 and 2 and countries in capital-abundant cone, $\overline{k}_c \in (\tau_1, \tau_2)$, produce good 2 and 3. Factor prices are equalize across countries within a same cone, but not across cones. Furthermore, the derivative of output with respect to endowments (i.e., Rybczynski derivative) varies with cone in which a country resides. It suggest that there exist distinct general equilibrium linkages between factor endowments, sectoral production, and factor prices across countries in the different cones. Panel B of Figure 2 demonstrates industry development path of the two-cone model. The capital–labor ratio cutoff where changes in the Rybczynski derivatives take place, $\overline{k} = \tau_1$, is called the interior knot.

In general, industry development path of the T-cone model with $I = T + 1$ goods is a spline with $T - 1$ knots. Econometric specification is,

$$q_{ic} = \beta_{1i} + \textstyle\sum_{t=1}^{T} \beta_{2it}\overline{k}_c I_t \left(\overline{k}_c < \tau_t\right) + \varepsilon_{ic} \tag{1}$$

where subscripts indicate country c and sector i. $I(\bullet)$ is the indicator function that equals 1 if the relationship in parenthesis is true and 0 otherwise. ε is the disturbance. Note that the location of knots τ's is irrespective of industry.

and indeterminacy of outputs occurs. See Melvin (1968) for a detailed explanation.

B. Structural Change of Cones

Previous subsection demonstrates that the prevailing exogenous goods prices and production technologies characterize the equilibrium at each point in time. It means that change in those parameters may alter the equilibrium conditions. This subsection demonstrate an example where the structure of cones changes over time. Since the direct effects of trade liberalization on goods prices and production technology are ambiguous, I consider the effect of international factor mobility that seems to be relevant for the EU. My empirical analysis is based on year-by-year estimation and it does not incorporate the dynamic adjustment itself. Thus, the intention here is to illustrate a potential mechanism that may affect the equilibrium.

By acknowledging the empirical evidences for the multiple cones in the previous works, suppose that the economy initially exhibits the two-cone equilibrium. Assume that there are two countries A and B located in the different cones. Figure 3 illustrates that the mix of factor endowments of country A and B, denoted by $A(\overline{K}_A, \overline{L}_A)$ and $B(\overline{K}_B, \overline{L}_B)$, lie in the labor- and capital-abundant cone respectively. Two downward-sloping isocost lines indicate that the interest rate is higher in country A and the wage is higher in country B.

Following Leamer (1995), assume that two countries' factor markets are partly integrated. In this instance, differences in factor prices create incentives for labor to flow from country A to B and for capital to flow from B to A. In the figure, two countries' factor endowments after the factor movements are indicated by point A' and B'. The factor movements in search of higher returns coincidentally change the supplies of three goods; supplies of good 1 and 3 will be decreased and supply of good 2 will be increased. If these changes are sufficiently large to affect the goods prices, unit value isoquants of good 1 and 3 shift inward (price increase) and isoquant of good 2 shifts outward (price decline). New isocost curves are defined by (r'_L, w'_L) and (r'_K, w'_K). The figure demonstrates that the difference in factor prices between two cones diminish. It suggest that continuous factor movements finally leads to a single-cone equilibrium where three sectors' isoquants are tangent to a single isocost curve. This simple analysis suggest that international factor movements may "melt away" the multiple cones and drive countries to converge into a single cone.

This scenario seems to be relevant for the EU where international factor mobility is liberalized along with the economic integration. In particular, a number of literature

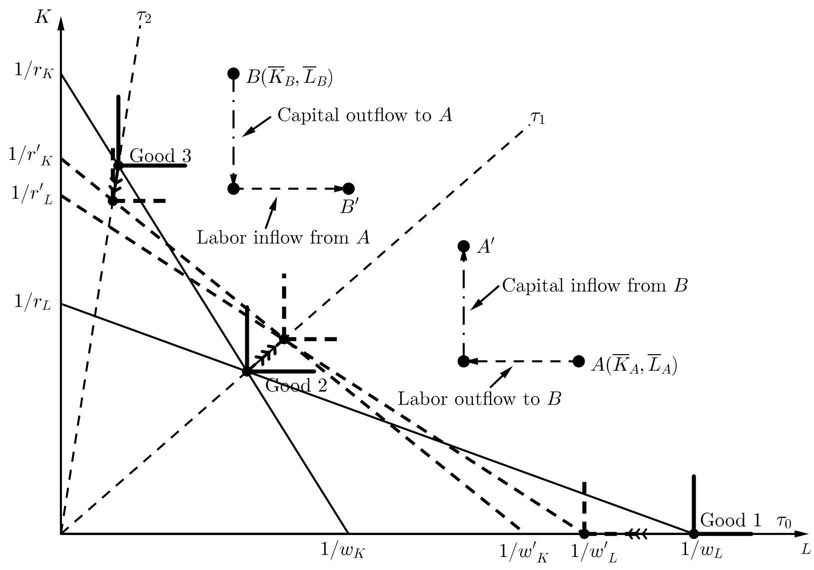


Figure 3. Effect of the International Factor Mobility in the Two-Cone World

Note: Basic structure is based on Leamer (1995)

demonstrates increasing foreign direct investment from the original member states (EU-15) to the new member states (CEECs) during the period from the late 1990s to the mid 2000s, e.g., Kärkkäinen (2008). If the factor mobility in the EU is significant, the EU countries may exhibit shift into a single-cone. Next section examines the evidence.

III. Estimating Development Path

A. Data

This section performs year-by-year estimation of development path for the single- and multiple-cone model. I make use of cross-section of value-added, capital stock, and employment data for 22 EU member states during the period from 1995 to 2006. Countrywide endowments are drawn from the Penn World Table (PWT) complied by Feenstra, Inklaar and Timmer (2015). We use data for capital stock using prices for structures and equipment that are constant across countries. Thus, capital stock data is comparable across countries. Following Hall and Jones (1999), employment data are corrected for educational differences and the data on educational attainment are retrieved from Barro and Lee (2013).[11] Countrywide capital–labor ratio and Eurostat two-letter abbreviation

[11]The quality-adjusted labor force in year t is computed as $\overline{L}^{adj} = L_{S0} + L_{S2} \times \exp(2 \times 0.134) + L_{S4} \times \exp(4 \times 0.134) + L_{S6} \times \exp(4 \times 0.134 + 2.101) + L_{S8} \times \exp(4 \times 0.134 + 4.101) + L_{S10} \times \exp(4 \times 0.134 + 4.101 + 2 \times 0.068) +$

codes are presented in Table 1. Countries are listed in ascending order of capital–labor ratio as of 1995. Countries with lower case abbreviations are the new member states. Cross-country variation in capital–labor ratio is relatively stable over time, with the coefficient of variation (CV) fluctuating between 0.40 to 0.45. The stable variation of capital–labor ratio implies that the change in the structure of cones, if any, is more likely to be triggered by the changes in goods prices and production technologies rather than the change in factor endowments.

Industry data are retrieved from the United Nation Industrial Development Organization (2014). The dataset covers 23 International Standard Industrial Classification (ISIC) industries in manufacturing sectors. For several countries, data for two or more ISIC industries are combined into a larger one. Following Koren and Tenreyro (2007), I aggregate sectors in order to obtain a consistent classification across countries and years.[12]. Sectoral value-added is expressed in 2005 US dollars, computed using the exchange rates and GDP deflator from the PWT.

Since ISIC groups output loosely according to similarity of end use, capital intensity of each ISIC industry may vary across countries and years, i.e., the intra-industry product heterogeneity is present. Adopting Schott's (2003) technique, ISIC industries are recast into theoretically more appropriate"HO aggregates." In order to preserve evenness, for T-cone model, I group ISIC industries into $I = T+1$ HO aggregates by defining T capital intensity cutoffs h's:

$$X_{ic} = \textstyle\sum_{k_{nc}\in(h_{i-1},h_i]} Q_{nc} \tag{2}$$

where X_{ic} denotes value-added of HO aggregate i in country c which is the sum of value added of all ISIC industry n with capital intensity between h_{i-1} and h_i ($h_0 = 0$). Capital intensities of ISIC industries are computed using gross fixed capital formation and employment data from the UNIDO databse. Investment data are denominated in 2005 US dollars, computed using the exchange rate and price level of capital formation from the PWT. Following Hall and Jones (1999), we adopt the perpetual inventory method. We use data from 1963 and apply a constant depreciation rate of 13.3%[13]. Missing

$L_{S12} \times \exp(4 \times 0.134 + 4.101 + 4 \times 0.068) + L_{S14} \times \exp(4 \times 0.134 + 4.101 + 6 \times 0.068)$, where L_{Se} is the fraction of employees with $e \in (e-2, e]$ years of education for $e \geq 2$ and L_{S0} is the number of employees with no education.

[12]The classification is not completely consistent across countries after this aggregation. However it is not so problematic since we recast ISIC industries into HO aggregates (explained below) based on the capital intensity.

[13]If year t_0 is the first year of investment data available, the capital stock in year t_0 is estimated by $I_{t_0}/(g+\delta)$

TABLE 1—CAPITAL–LABOR RATIO AND EUROSTAT CODES OF SAMPLE COUNTRIES

Country	Abbreviation	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bulgaria	bg	17.7	16.6	15.6	15.5	15.8	16.4	16.8	17.0	13.2	13.9	15.7	17.2
Latvia	lv	23.3	22.8	18.2	20.3	22.4	24.0	25.4	21.8	21.7	22.3	23.6	24.9
Hungary	hu	28.6	26.5	25.5	24.4	23.3	24.7	28.5	27.3	29.9	31.7	33.1	38.1
Poland	pl	29.1	29.1	28.0	27.7	28.9	27.5	28.2	29.9	29.7	30.9	31.8	30.5
Slovenia	si	32.8	34.3	36.4	37.9	39.2	40.9	41.5	**39.0**	40.7	**48.0**	**55.2**	**56.4**
Slovakia	sk	33.0	33.1	31.4	30.1	29.2	30.4	30.5	29.5	30.0	32.5	31.6	34.5
Czech Republic	cz	33.3	34.6	30.8	30.8	30.9	31.5	32.4	32.5	35.3	37.2	38.5	42.2
Malta	mt	42.0	42.8	48.9	56.8	57.1	**60.6**	**56.2**	**56.7**	**56.0**	**58.3**	**56.8**	**64.3**
Sweden	SE	50.6	50.2	49.8	47.9	46.4	45.5	**43.9**	**42.4**	**43.7**	43.4	41.0	46.9
United Kingdum	UK	51.0	50.3	49.0	48.7	46.7	47.4	**45.9**	**44.9**	**45.7**	45.8	**50.4**	**53.1**
Netherlands	NL	61.6	55.7	54.3	53.4	52.2	52.4	**51.7**	**52.6**	**55.6**	**59.9**	**64.1**	**70.9**
Ireland	IE	63.1	62.2	57.7	51.3	45.7	42.7	38.6	**38.7**	38.8	41.7	44.0	**57.5**
Portugal	PT	65.6	63.9	56.5	53.5	53.8	55.1	**54.2**	**57.2**	**61.7**	**66.7**	**72.4**	**80.7**
Denmark	DK	66.6	64.6	63.0	61.6	60.4	55.4	**57.4**	**56.9**	**59.4**	**63.9**	**67.5**	**71.8**
Greece	EL	72.9	72.2	71.7	68.9	68.1	**68.9**	**62.1**	**60.7**	**62.3**	**64.8**	**64.6**	**73.1**
France	FR	74.2	73.0	71.5	69.2	66.4	**65.6**	**65.3**	**65.2**	**65.3**	**76.9**	**84.0**	**94.5**
Belgium	BE	79.9	79.2	77.6	74.0	74.5	**76.5**	**77.3**	**74.4**	**78.0**	**83.6**	**87.1**	**94.8**
Cyprus	cy	80.6	82.1	81.8	81.0	79.9	**80.8**	**85.3**	**83.1**	**75.8**	**80.8**	**85.5**	**92.7**
Austria	AT	86.5	87.2	87.0	90.4	88.3	**88.6**	**87.1**	**84.7**	**85.8**	**89.5**	**92.2**	**97.8**
Spain	ES	90.2	89.3	83.7	80.1	72.2	**70.4**	**64.9**	**65.4**	**67.6**	**73.6**	**76.0**	**93.5**
Finland	FI	97.5	89.9	84.8	84.1	82.2	**82.4**	**83.1**	**78.6**	**81.1**	**85.2**	**94.0**	**99.4**
Italy	IT	114.8	113.1	112	101.5	98.5	**98.0**	**95.2**	**92.2**	**92.2**	**97.8**	**108.1**	**118.6**
Min		17.7	16.6	15.6	15.5	15.8	16.4	16.8	17.0	13.2	13.9	15.7	17.2
Max		114.8	113.1	112.0	101.5	98.5	98.0	95.2	92.2	92.2	97.8	108.1	118.6
Mean		58.9	57.8	56.1	55.0	53.7	53.9	53.2	52.3	53.2	56.7	59.9	66.1
CV = Sandard Deviation/Mean		0.44	0.44	0.45	0.43	0.42	0.42	0.41	0.41	0.40	0.41	0.42	0.42

Note: Unit is thousand USD. Countries are listed in ascending order of capital–labor ratio as of 1995. For the years from 2000, bold figure indicates that the capital–labor ratio exceeds the estimated interior knot location (τ_1) of the two-cone model, i.e., the country resides in the capital-abundant cone.

values are linearly interpolated. We also apply the quality correction to employment data explained above.

B. Estimation Strategy

By using outputs of HO aggregates, I estimate development paths for single- and multiple-cone models year-by-year. Equation (1) is the regression equation. q_{ic} is replaced by $x_{ic} \equiv X_{ic}/\overline{L}_c$. In the T-cone model, T capital intensity cutoffs (h's) and $T-1$ interior knots (τ's) should be given in the estimation. Following Schott (2003) and Kiyota (2012), I employ a grid search approach to estimate these parameters. We grid the overall possible combinations of h's and τ's for a given interval size. For the interval sizes, I use an interval of $\gamma = 0.01$ for capital intensity cutoffs ($10^{0.001} \leq 10^{\gamma}(= h) \leq 10^{3.00}$, in thousand USD). For the interior knots, we apply an interval size of 500 USD. $\tau_0 = 0$ and τ_T is assumed to be 1,000 USD above the upper range of the sample's observed capital-labor ratio in each year.

For given capital intensity cutoffs and interior knots, intercepts and slopes of the development paths (β's) are estimated simultaneously via a seemingly unrelated regressions (SUR) model. In the estimation, the shape of each development paths is constrained as implied by the Figure 2. The development path of the most labor-intensive HO aggregate, for example, must have negative slope for the first segment and meet the $\overline{k}$-axis at the location of the first estimated interior knot; and following segments must lie along the k-axis.

For every combination of the capital-intensity cutoffs and the interior knots, I estimate β's iteratively. Since each pattern of estimation can be regarded as a different econometric model, I compare a goodness-of-fit statistics and choose the model that provide the best fit. In this model selection process, I firstly rule out models that violate the theoretical conditions with respect to per capita output at knots;[14]

(3) $$\beta_{11} < \beta_{221}(\tau_1 - \tau_0) < \beta_{232}(\tau_2 - \tau_1) < ... < \beta_{2,T+1,T}(\tau_T - \tau_{T-1})$$

Secondly, I choose the combination of the h's and τ's that maximizes the Berndt's

where I_{t_0} is the investment in t_0, g is the average geometric growth rate from t_0 to 1979 of the investment series, and δ is a depreciation rate. If the sequence between t_0 and 1979 is less than five years, we use the first five years available to calculate g.

[14]Equation (3) is derived from the conditions to assure the equilibrium; per capita output of sector i at $\overline{k} = k_i$, i.e., $x_i|_{\overline{k}=k_i}$ for $i \in (1, I)$, should hold $x_1|_{\overline{k}=k_1} < x_2|_{\overline{k}=k_2} < ... < x_I|_{\overline{k}=k_I}$. See also Figure 2.

(1991) generalized R^2. Note that maximization of R^2 is essentially equivalent to the concept of maximum likelihood method that is employed in Schott (2003) and Kiyota (2012). See Appendix for the derivation of the generalized R^2.

After fitting single-cone model and multiple-cone models respectively, we test the null hypothesis of the single-cone model against the alternative multiple-cone models. Because single- and multiple-cone models are non-nested, the classical likelihood test cannot be applied. I follow Schott (2003) and construct bootstrap confidence intervals to compute relative fit of the models. While a single-cone model has five parameters to be estimated, a two cone model, for example, has twelve parameters. In order to impose a penalty for increasing number of parameters, I employ difference in Aakaike's Information Criteria (AIC) for the relative fit measurement.[15] See Appendix for the detailed explanation on this bootstrap procedure.

C. Estimation Results

Table 2 summarize the estimation results of the year-by-year estimation of the industry development path for single- and multiple-cone models. Due to the small number of observation, number of cones is constrained up to three. The right most column exhibits the Bootstrap P-values indicating the fit of single- and multiple-cone model. The single-cone model is not rejected against alternative multiple-cone models from 1995 to 1999. However, there is strong evidence for the two-cone model after 2000 with bootstrap P-value less than 1%. Since the testing of null hypothesis of a single-cone model against alternative multiple-cone hypotheses builds upon the Neyman-Pearson framework and focuses on the Type-I error, empirical results for the years from 1995 to 1999 do not simply support the single-cone equilibrium. However, my results confirm that the two-cone structure is more significant in the 2000s. It suggests that the EU countries exhibit more diversified production patterns in the 2000s. One plausible interpretation of this finding may attribute to the trade liberalization between the capital-abundant original member countries and the labor-abundant new member states in the late 1990s. As a result of the market integration, the international division of labor across countries may have become more evident in accordance with their relative factor endowments. Furthermore, persistence of the two-cone structure after 2000 does not support the claim that the economic integration may drive economy to exists a single-cone equilibrium

[15]See Cameron and Trivedi (2005) for a detailed explanation on AIC.

through the factor movements. It suggests that the factor mobility within the EU is not sufficient to melt away the existence of multiple cones.

In order to compare a performance of the models across years, Table 3 provide the mean absolute percentage prediction errors of each HO aggregate regression.[16] For years between 1995 and 1999, prediction errors for the single-cone model with two HO aggregates are presented. For the period after 2000, prediction errors for the favored two-cone model with three HO aggregates are listed. The rightmost column is the average across two or three HO aggregates. The fit of the single-cone model deteriorate from 1995 to 1999, as the generalized R^2 declines from 0.656 in 1995 to 0.381 in 1999. Similar trend is observed for the mean absolute prediction error. The average error of the single-cone model is increasing, from 66.3% in 1995 to 100.7% in 1999. The goodness-of-fit statistics for the favored two-cone model from 2000 to 2006 is higher than that for the single-cone model in the 1990s. The generalized R^2 jumped from 0.549 in 2000 to 0.973 in 2001, and it fluctuates between 0.901 and 0.977 afterward. The mean absolute prediction error fluctuates between 47.0 and 99.6 during the period from 2000 to 2006.

Table 4, 5, and 6 present the coefficient estimates of the single-cone model for 1995–1999, the favored two-cone model for 2000–2003, and that for for 2004–2007, respectively. Signs of all coefficients are consistent with theoretical predictions and statistically significant at the 99% level. Figure 4–15 plot the estimated development paths for each year. The development path of the single-cone model is presented for the years 1995–1999 and that for the two-cone model is presented for the years from 2000. In each figure, HO aggregates are ordered by increasing capital intensity from left to right, and down. Each observation is identified by the two-letter Eurostat country code. Confidence intervals (95%) for positively or negatively sloped segments provide a sense of precision with which they are estimated.

The theory states that the single-cone model has countries producing both of two goods. However, the estimated single-cone development path exhibits several countries with zero production of the labor-intensive HO aggregates. Observations with zero output are particularly substantial for 1998 and 1999. It implies that these countries specialize completely in the capital-intensive HO aggregate. Although the single-cone model is not rejected, these deviation are reflected in the higher mean absolute prediction error

[16]Mean absolute prediction error is computed by $100 \times \frac{1}{C}\sum_c \left(\frac{|x_{ic} - \hat{x}_{ic}|}{x_{ic}}\right)$ where x_{ic} is actual observation of per capita valued added of HO aggregate i in country c and $\hat{x}_{ic}$ is the corresponding fitted value. C is the number of observations.

presented in the Table 3.

In case of the two-cone equilibrium, the theory predicts that the intermediate capital-intensive HO aggregate is commonly produced by all countries and the first and third HO aggregate, respectively, is produced only by countries in labor- and capital-abundant cone. Inspection of Figure 9–15 reveals that there are several labor-abundant countries that do not produce the labor-intensive HO aggregate. On the other hand, the relatively high number of labor-abundant countries are producing the most capital-intensive HO aggregate. This finding is in line with Schott's (2003). It may be attributed to, for example, foreign direct investment from the developed countries that allows labor-abundant developing countries to produce more capital-abundant goods by exploiting the foreign capital and technology before their endowments let them profitable.

Finally, I inspect the distribution of countries across cones. For each year after 2000, estimated interior knot location classifies countries into labor- and capital-abundant cone. In the Table 1, boldface number indicate that the capital–labor ratio exceeds the interior knot location, i.e., the country resides in the capital-abundant cone. The table reveals that country composition in the two cones is relatively stable over time. Bulgaria, Latvia, Hungary, Poland, Slovakia, and Czech Republic always inhabit the labor-abundant cone. These countries are the new member states of the EU. On the other hand, Malta, Greece, France Belgium, Cyprus, Austria, Spain, Finland, and Italy reside in the capital-abundant cone for the entire period. Except for Malta and Cyprus, they are the original member states of the EU. For Netherlands, Portugal, and Denmark, they are grouped into the labor-abundant cone in 2000, they move to capital-abundant cone in 2001 and remain thereafter. The rest of the countries, Slovenia, Sweden, the United Kingdom, and Ireland, move backward and forward between the two cones. On the whole, the two-cone structure divide the EU member states into the original and new member states.

The countries in different cones have distinct general equilibrium linkage between factor endowments, sectoral production, and factor prices. As Davis (1996) discusses, wage-price arbitrate is dampened across countries in different cones. Thus the existence of the multiple cones suggest that workers in capital-abundant countries may be insulated from the price decline of the labor-intensive goods produced by the labor-abundant country. Furthermore, the relatively stable two-cone structure implies the persistent disparity in production patterns and factor prices across countries in the EU.

Table 2—Summary of Year-by-Year Estimations of Single- and Multiple-cone Development Path

Year	Num of cones	Capital intensity cutoffs h_1	h_2	h_3	Knots τ_1	τ_2	τ_3	R^2	AIC	Bootstrap P-value
1995	1	$10^{0.83}$	—	—	116	—	—	0.656	56.056	—
	2	$10^{0.40}$	$10^{1.18}$	—	36.5	116	—	0.654	65.664	0.368
	3	$10^{0.25}$	$10^{0.68}$	$10^{1.47}$	42	42.5	116	0.804	10.752	0.584
1996	1	$10^{1.08}$	—	—	115	—	—	0.626	77.098	—
	2	$10^{0.30}$	$10^{1.17}$	—	31	115	—	0.646	46.260	0.271
	3	$10^{0.30}$	$10^{0.72}$	$10^{1.33}$	43.5	44	115	0.759	11.332	0.991
1997	1	$10^{1.08}$	—	—	114	—	—	0.508	89.134	—
	2	$10^{0.58}$	$10^{1.31}$	—	41	114	—	0.626	69.110	0.164
	3	$10^{0.21}$	$10^{0.94}$	$10^{1.38}$	36.5	37	114	0.714	57.686	0.982
1998	1	$10^{1.02}$	—	—	103	—	—	0.485	89.728	—
	2	$10^{0.30}$	$10^{1.22}$	—	34.5	103	—	0.619	8.590	0.171
	3	$10^{0.20}$	$10^{0.53}$	$10^{1.22}$	20.5	32.5	103	0.684	−56.494	0.985
1999	1	$10^{1.02}$	—	—	100	—	—	0.381	93.020	—
	2	$10^{0.35}$	$10^{1.34}$	—	38.5	100	—	0.569	9.728	0.143
	3	$10^{0.35}$	$10^{0.54}$	$10^{1.40}$	39.5	40	100	0.587	−60.478	0.991
2000	1	$10^{1.04}$	—	—	99	—	—	0.351	98.228	—
	2	$10^{0.52}$	$10^{1.35}$	—	57.5	99	—	0.549	43.816	0.002
	3	$10^{0.25}$	$10^{0.49}$	$10^{1.36}$	41	41.5	99	0.649	−74.588	0.992
2001	1	$10^{0.91}$	—	—	97	—	—	0.351	57.480	—
	2	$10^{0.52}$	$10^{1.35}$	—	42.5	97	—	0.973	41.788	< 0.001
	3	$10^{0.28}$	$10^{0.52}$	$10^{1.34}$	20	40	97	0.994	−188.904	0.945
2002	1	$10^{1.18}$	—	—	94	—	—	0.377	98.856	—
	2	$10^{0.44}$	$10^{1.21}$	—	34	94	—	0.901	−25.96	0.01
	3	$10^{0.33}$	$10^{0.44}$	$10^{1.36}$	29	30	94	0.913	133.322	1.00
2003	1	$10^{1.19}$	—	—	94	—	—	0.389	102.170	—
	2	$10^{0.55}$	$10^{1.44}$	—	43.5	94	—	0.983	−50.718	< 0.001
	3	$10^{0.55}$	$10^{0.95}$	$10^{1.49}$	41.5	44.5	94	0.971	−40.028	1.00
2004	1	$10^{1.19}$	—	—	99	—	—	0.408	96.024	—
	2	$10^{0.52}$	$10^{1.43}$	—	47	99	—	0.971	−44.700	< 0.001
	3	$10^{0.35}$	$10^{0.88}$	$10^{1.49}$	22.5	43	99	0.999	−189.164	0.998
2005	1	$10^{1.15}$	—	—	110	—	—	0.412	74.354	—
	2	$10^{0.54}$	$10^{1.42}$	—	45	110	—	0.977	−33.034	< 0.001
	3	$10^{0.36}$	$10^{0.88}$	$10^{1.43}$	24	42.5	110	0.999	−171.682	0.991
2006	1	$10^{1.14}$	—	—	120	—	—	0.576	73.362	—
	2	$10^{0.54}$	$10^{1.33}$	—	49	120	—	0.946	−19.870	0.027
	3	$10^{0.55}$	$10^{0.96}$	$10^{1.33}$	45.5	46	120	0.762	−45.030	0.981

Note: Unit for capital intensity cutoffs and knots location is thousand USD. Rightmost column reports results of testing null hypothesis of a single-cone model against alternate hypotheses of up to three cones. Models are evaluated via bootstrap p-values. See text and Appendix for further details.

TABLE 3—MEAN ABSOLUTE PREDICTION ERROR

Year	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3	Mean
1995	100.4	32.2	—	66.3
1996	103.7	40.5	—	72.1
1997	136.0	37.8	—	86.9
1998	154.9	38.0	—	96.5
1999	158.6	42.8	—	100.7
2000	22.8	181.6	94.4	99.6
2001	8.0	100.9	69.3	59.4
2002	23.9	65.4	56.3	48.5
2003	9.0	115.2	87.7	70.6
2004	11.5	131.8	98.8	80.7
2005	12.0	135.0	75.3	74.1
2006	35.9	45.5	59.6	47.0

Note: For the years from 1995 to 1999, prediction errors of the single-cone model with two HO aggregates are presented. For the following years, prediction errors are computed for the estimation of the favored two-cone model with three HO aggregates.

Table 4—Coefficient Estimates for the Single-Cone Development Path: 1995–1999

	1995		1996		1997	
	HO Aggregate 1	HO Aggregate 2	HO Aggregate 1	HO Aggregate 2	HO Aggregate 1	HO Aggregate 2
β_1	0.408***	—	1.024***	—	0.920***	—
	(0.102)		(0.152)		(0.164)	
β_{21}	−0.004***	0.046***	−0.009***	0.041***	−0.008***	0.044***
	(0.001)	(0.003)	(0.001)	(0.003)	(0001)	(0.004)
Obs.	22	22	22	22	22	22
RMSE	0.219	0.944	0.348	0.994	0.374	1.208
Constraints	$\beta_1 + 116\beta_{21} = 0$	$\beta 1_1 = 0$	$\beta_1 + 115\beta_{21} = 0$	$\beta 1_1 = 0$	$\beta_1 + 114\beta_{21} = 0$	$\beta 1_1 = 0$
Capital intensity cutoffs	$h_1 = 10^{0.83}$		$h_1 = 10^{1.08}$		$h_1 = 10^{1.08}$	
Knots	$\tau_1 = 116$		$\tau_1 = 115$		$\tau_1 = 114$	
Generalized R^2	0.656		0.626		0.508	
AIC	56.056		77.098		89.134	

	1998		1999	
	HO Aggregate 1	HO Aggregate 2	HO Aggregate 1	HO Aggregate 2
β_1	0.758***	—	0.711***	—
	(0.172)		(0.154)	
β_{21}	−0.007***	0.048***	−0.007***	0.050***
	(0.002)	(0.004)	(0.002)	(0.004)
Obs.	22	22	22	22
RMSE	0.368	1.261	0.338	1.49
Constraints	$\beta_1 + 103\beta_{21} = 0$	$\beta 1_1 = 0$	$\beta_1 + 100\beta_{21} = 0$	$\beta 1_1 = 0$
Capital intensity cutoffs	$h_1 = 10^{1.02}$		$h_1 = 10^{1.02}$	
Knots	$\tau_1 = 103$		$\tau_1 = 100$	
Generalized R^2	0.485		0.381	
AIC	89.728		93.020	

Note: Estimation by a seemingly unrelated regressions model. Standard errors are bootstrapped (1000 replications) in order to obtain heteroskedasticity robust standard errors and presented in parenthesis. Stars indicate the level of significance; *** $p < 0.01$.

Table 5—Coefficient Estimates for the Favored Two-Cone Development Path: 2000–2003

	2000			2001		
	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3
β_1	0.142***	—	—	0.159***	—	—
	(0.020)			(0.013)		
β_{21}	−0.002***	0.037***	—	−0.005***	0.048***	—
	(0.000)	(0.004)		(0.000)	(0.004)	
β_{22}	0.002***	−0.087***	0.131***	0.005***	−0.085***	0.086***
	(0.000)	(0.011)	(0.024)	(0.000)	(0.007)	(0.011)
Obs.	22	22	22	22	22	22
RMSE	0.029	0.670	2.164	0.007	0.571	1.591
Constraints	$\beta_1 + 57.5\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$	$\beta_1 + 42.5\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$
	$\beta_{21} + \beta_{22} = 0$	$57.5\beta_{21} + 41.5(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$	$\beta_{21} + \beta_{22} = 0$	$42.5\beta_{21} + 54.5(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$
Capital intensity cutoffs		$h_1 = 10^{0.52}$, $h_2 = 10^{1.35}$			$h_1 = 10^{0.52}$, $h_2 = 10^{1.35}$	
Knots		$\tau_1 = 57.5$, $\tau_2 = 99$			$\tau_1 = 42.5$, $\tau_2 = 97$	
Generalized R^2		0.549			0.973	
AIC		43.816			41.788	

	2002			2003		
	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3
β_1	0.233***	—	—	0.171***	—	—
	(0.037)			(0.007)		
β_{21}	−0.007***	0.039***	—	−0.004***	0.053***	—
	(0.001)	(0.004)		(0.000)	(0.004)	
β_{22}	0.007***	−0.061***	0.083***	0.004***	−0.099***	0.081***
	(0.001)	(0.006)	(0.009)	(0.000)	(0.007)	(0.010)
Obs.	22	22	22	22	22	22
RMSE	0.011	0.418	1.934	0.006	0.670	1.638
Constraints	$\beta_1 + 34\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$	$\beta_1 + 43.5\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$
	$\beta_{21} + \beta_{22} = 0$	$34\beta_{21} + 60(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$	$\beta_{21} + \beta_{22} = 0$	$43.5\beta_{21} + 50.5(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$
Capital intensity cutoffs		$h_1 = 10^{0.44}$, $h_2 = 10^{1.21}$			$h_1 = 10^{0.55}$, $h_2 = 10^{1.44}$	
Knots		$\tau_1 = 34$, $\tau_2 = 94$			$\tau_1 = 43.5$, $\tau_2 = 94$	
Generalized R^2		0.901			0.983	
AIC		−25.960			−50.718	

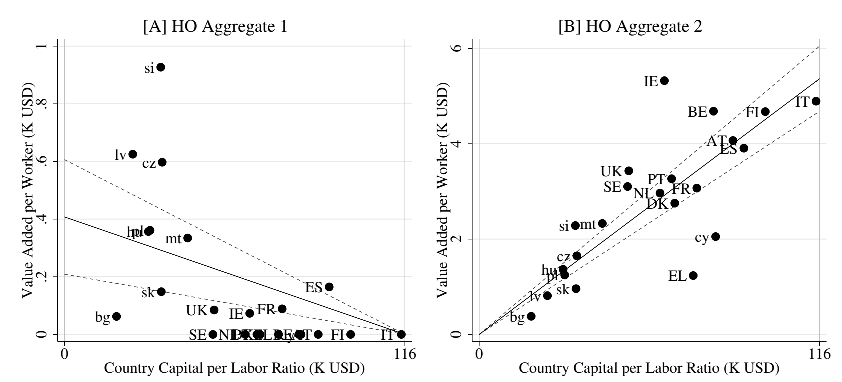
Note: See footnote in Table 4.

Table 6—Coefficient Estimates for the Favored Two-Cone Development Path: 2004–2007

	2004			2005		
	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3
β_1	0.160***	—	—	0.153***	—	—
	(0.010)			(0.009)		
β_{21}	−0.003***	0.049***	—	−0.003***	0.048***	—
	(0.000)	(0.004)		(0.000)	(0.003)	
β_{22}	0.003***	−0.093***	0.075***	0.003***	−0.082***	0.062***
	(0.000)	(0.008)	(0.010)	(0.000)	(0.006)	(0.007)
Obs.	22	22	22	22	22	22
RMSE	0.007	0.608	1.487	0.005	0.507	1.315
Constraints	$\beta_1 + 47.0\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$	$\beta_1 + 45.0\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$
	$\beta_{21} + \beta_{22} = 0$	$47.0\beta_{21} + 52.0(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$	$\beta_{21} + \beta_{22} = 0$	$45.0\beta_{21} + 65.0(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$
Capital intensity cutoffs		$h_1 = 10^{0.52}$, $h_2 = 10^{1.43}$			$h_1 = 10^{0.54}$, $h_2 = 10^{1.42}$	
Knots		$\tau_1 = 47$, $\tau_2 = 99$			$\tau_1 = 45$, $\tau_2 = 110$	
Generalized R^2		0.971			0.977	
AIC		−44.700			−66.034	

	2006			2007		
	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3	HO Aggregate 1	HO Aggregate 2	HO Aggregate 3
β_1	0.128***	—	—	0.160***	—	—
	(0.029)			(0.010)		
β_{21}	−0.003***	0.035***	—	−0.003***	0.049***	—
	(0.001)	(0.003)		(0.000)	(0.004)	
β_{22}	0.003***	−0.060***	0.063***	0.003***	−0.093***	0.075***
	(0.001)	(0.005)	(0.008)	(0.000)	(0.008)	(0.010)
Obs.	22	22	22	22	22	22
RMSE	0.013	0.477	1.402	0.007	0.608	1.487
Constraints	$\beta_1 + 49.0\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$	$\beta_1 + 47.0\beta_{21} = 0$	$\beta_1 = 0$	$\beta_1 = 0$
	$\beta_{21} + \beta_{22} = 0$	$49.0\beta_{21} + 71(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$	$\beta_{21} + \beta_{22} = 0$	$47.0\beta_{21} + 52.0(\beta_{21} + \beta_{22}) = 0$	$\beta_{21} = 0$
Capital intensity cutoffs		$h_1 = 10^{0.54}$, $h_2 = 10^{1.33}$			$h_1 = 10^{0.52}$, $h_2 = 10^{1.43}$	
Knots		$\tau_1 = 49$, $\tau_2 = 120$			$\tau_1 = 47$, $\tau_2 = 99$	
Generalized R^2		0.779			0.971	
AIC		−19.870			−44.700	

Note: See footnote in Table 4.



Note: Estimation by constrained SUR. Dashed lines represent the 95% confidence interval.

FIGURE 4. ESTIMATED DEVELOPMENT PATH FOR FAVORED SINGLE-CONE MODEL: 1995

Note: Estimation by constrained SUR. Dashed lines represent 95% confidence interval.

IV. Concluding Remarks

This paper tests empirically the production side of the HO model and investigates whether the EU member states exhibit convergence of divergence in production patterns over time. In particular, I focus on the two types of equilibria; the single-cone equilibrium with all countries producing all goods and the multiple-cone equilibrium with variation in production patterns across countries. Since the equilibria of HO framework are characterized by the prevailing goods prices and production technologies at each point in time, changes in those parameters may alter the equilibrium conditions and structure of cones. By testing the single- versus multiple-cone models, I examine whether the structure of cones remains or evolves over time.

Using a cross-section of countries endowments and sectoral output data for the 22 EU member states from 1995 to 2006, and adopting an empirical methodology proposed by Schott (2003), this paper performs year-by-year estimation of industry development path of single- and multiple-cone models. Results reveal that the null hypothesis of the single-cone equilibrium is not rejected against the alternative multiple-cone model for the years from 1995 to 1999. However, I find the strong empirical support for the HO specialization in favor of the two-cone equilibrium after 2000. It suggests that production patterns in the EU member states become more diverged in the 2000s. In other words, classification of countries based on their product mix is more evident; one group specializes in more labor-intensive subset of goods and the other specializes in more capital-intensive subset. Inspection of country composition in the two cones reveals that the labor- and

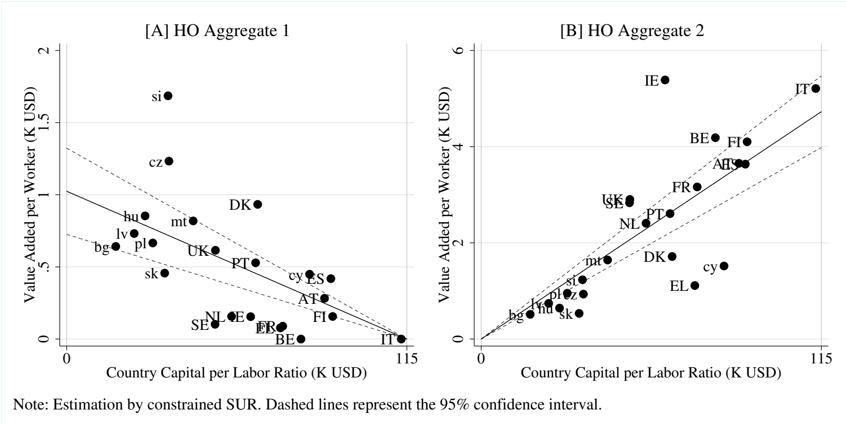


FIGURE 5. ESTIMATED DEVELOPMENT PATH FOR SINGLE-CONE MODEL: 1996

Note: See notes of Figure 4

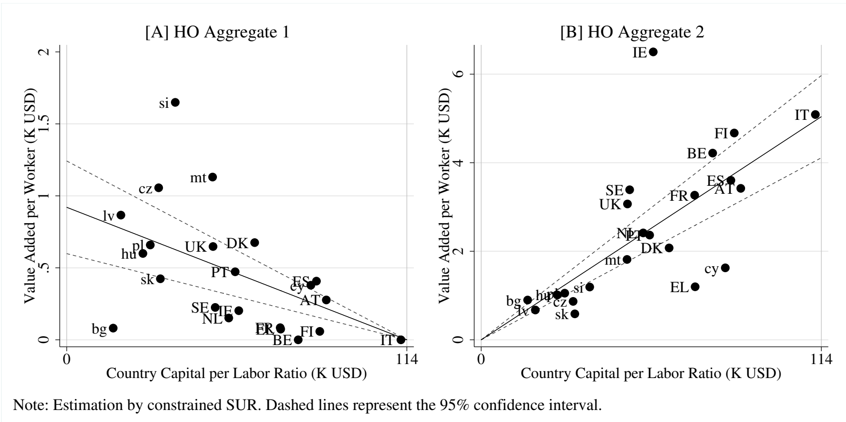


FIGURE 6. ESTIMATED DEVELOPMENT PATH FOR SINGLE-CONE MODEL: 1997

Note: See notes of Figure 4

capital-abundant cones consist of, broadly speaking, the new and original member states, respectively. Due to the trade liberalization between capital-abundant original member states and labor-abundant new member states, international division of labor may have been enhanced in the EU according to countries' relative factor endowments.

Furthermore, results demonstrate that the two-cone equilibrium remains by the end of the sampled period. It implies that there exists persistent diversity in production patterns. Since the HO model builds on the general equilibrium framework, the evidence for the two cones may shed light on the underlying elements of factor price differences across countries. Simply put, the observed difference in factor prices across EU may be explained partly by the difference in production mix and the rest of the factor may be

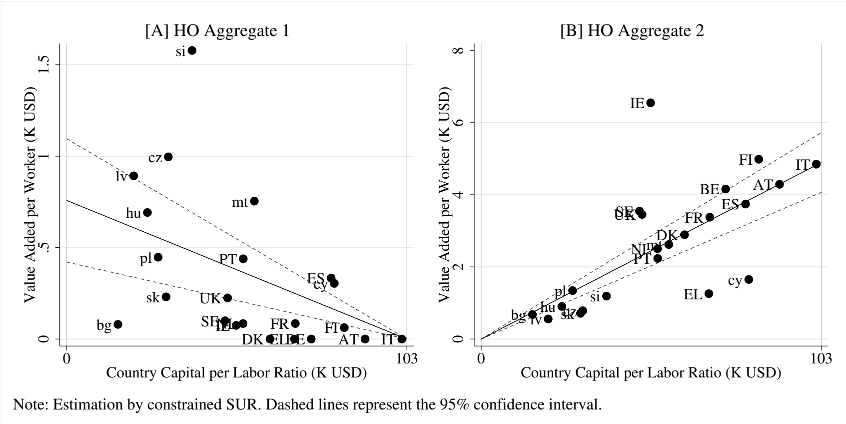


Figure 7. Estimated Development Path for Single-Cone Model: 1998

Note: See notes of Figure 4

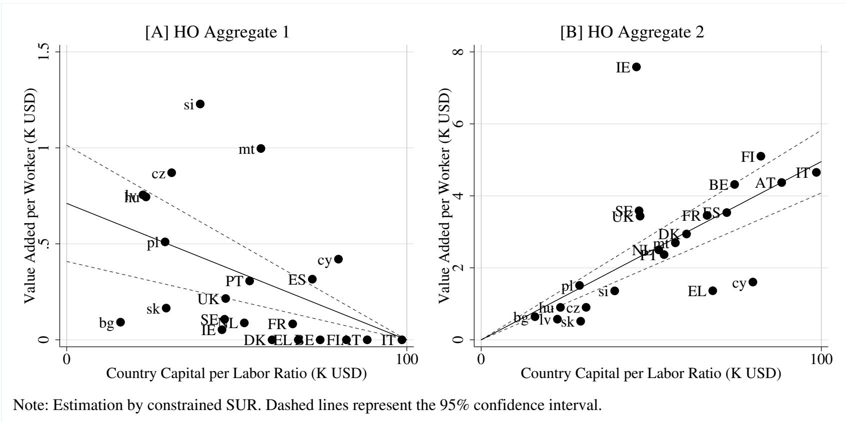
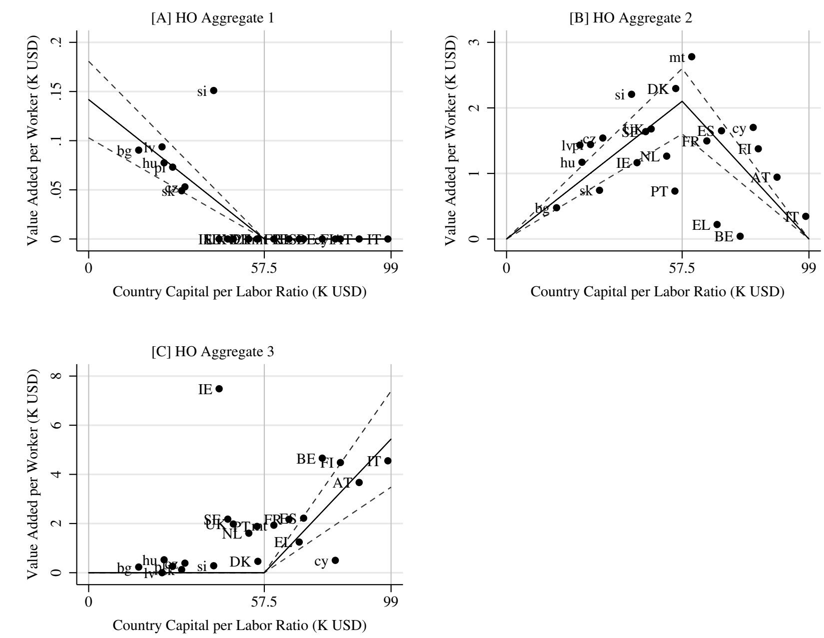


Figure 8. Estimated Development Path for Single-Cone Model: 1999

Note: See notes of Figure 4

attributed to the technological or educational gaps. Moreover, factor mobility in search of higher factor rewards will be expected to occur due to the further economic integration in the EU.

There are several future tasks that are worth mentioning. Firstly, although use of the HO aggregates is effective to she the light on the intra-industry product heterogeneity across countries, it obscure the actual industry structure. Analysis using finer sectoral or even product level data is important to investigate the inter- and intra-industry specialization along with the trade liberalization. Secondly, my analysis solely focus on the production side of the HO framework and does not account trade patterns. It may be important to analyze the production linkage across EU countries by utilizing the inter-



Note: Estimation by constrained SUR. Dashed lines represent the 95% confidence interval.

FIGURE 9. ESTIMATED DEVELOPMENT PATH FOR FAVORED TWO-CONE MODEL: 2000

Note: See notes of Figure 4

national input-output table. Finally, the effect of factor mobility should be explicitly considered in analyzing the change in production patterns. These are beyond the scope of this paper and await future research.

REFERENCES

Amiti, Mary. 1999. "Specialization patterns in Europe." *Weltwirtschaftliches Archiv*, 135(4): 573–593.

Barro, Robert J., and Jong Wha Lee. 2013. "A new data set of educational attainment in the world, 1950-2010." *Journal of Development Economics*, 104: 184–198.

Batista, Catia, and Jacques Potin. 2014. "Stages of diversification in a neoclassical world." *Economics Letters*, 122(2): 276–284.

Ben-David, Dan. 1993. "Equalizing Exchange : Trade Liberalization and Income Convergence." *Quarterly Journal of Economics*, 108(3): 653–679.

Berndt, Ernst R. 1991. *The Practice of Econometrics: Classic and Contemporary.* Reading, MA:Addison-Wesley Publishing Company.

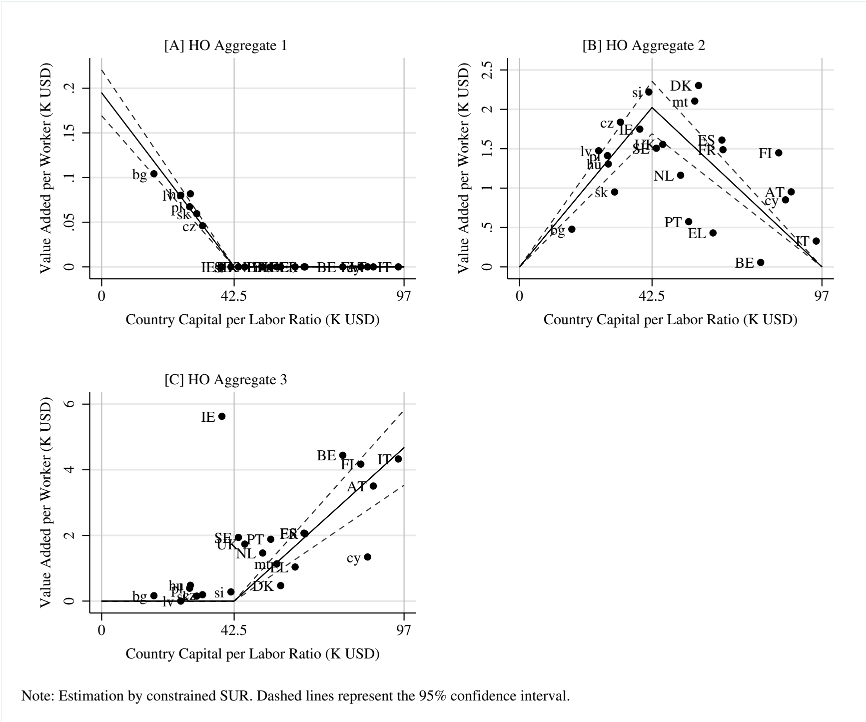


FIGURE 10. ESTIMATED DEVELOPMENT PATH FOR FAVORED TWO-CONE MODEL: 2001

Note: See notes of Figure 4

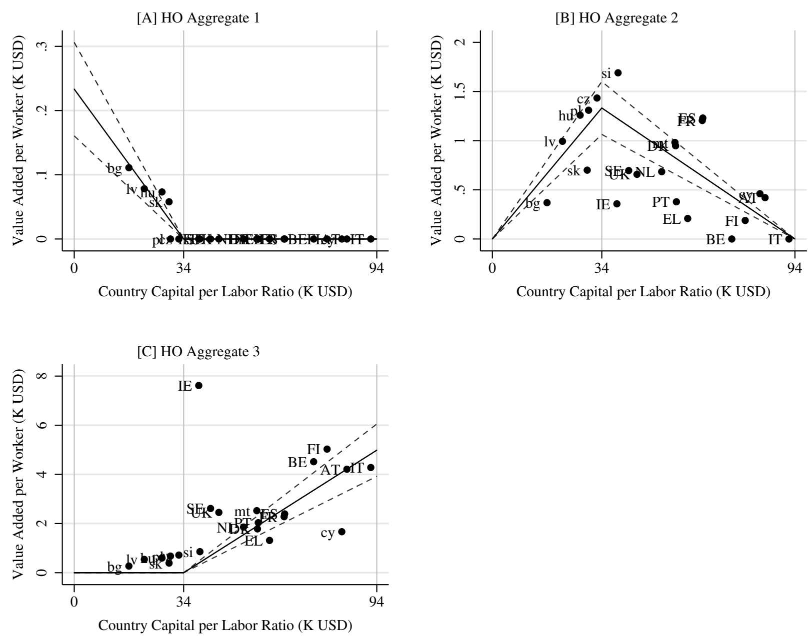
Bernstein, Jeffrey R., and David E. Weinstein. 2002. "Do endowments predict the location of production? Evidence from national and international data." *Journal of International Economics*, 56(1): 55–76.

Cameron, A. Colin, and Pravin K Trivedi. 2005. *Microeconomics: Methods and Applications.* New York:Cambridge University Press.

Crespo, Nuno, and Maria Paula Fontoura. 2007. "Integration of CEECs into EU market: Structural change and convergence." *Journal of Common Market Studies*, 45(3): 611–632.

Davis, Donald R. 1996. "Trade Liberalization and income distribution." *NBER Working Paper*, 5693: 1–17.

Davis, Donald R., David E. Weinstein, Scott C. Bradford, and Kazushige Shimpo. 1997. "Using International and Japanese Regional Data to Determine When the Factor Abundance Theory of Trade Works." *American Economic Review*, 87(3): 421–446.



Note: Estimation by constrained SUR. Dashed lines represent the 95% confidence interval.

FIGURE 11. ESTIMATED DEVELOPMENT PATH FOR FAVORED TWO-CONE MODEL: 2002

Note: See notes of Figure 4

Deardorff, Alan V. 1994. "The possibility of factor price equalization, revisited." *Journal of International Economics*, 36(1-2): 167–175.

Deardorff, Alan V. 2001. "Rich and Poor Countries in Neoclassical Trade and Growth." *Economic Journal*, 111(470): 277–294.

Deardorff, Alan V. 2014. *Terms of Trade: Glossary of International Economics.* . 2nd ed., Singapore:World Scientific Publishing Company.

Debaere, Peter, and Ufuk Demiroglu. 2003. "On the similarity of country endowments." *Journal of International Economics*, 59(1): 101–136.

European Commission. 2007. "EU industrial structure "Competitiveness and Economic Reforms"."

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. "The next generation of the penn world table." *American Economic Review*, 105(10): 3150–3182.

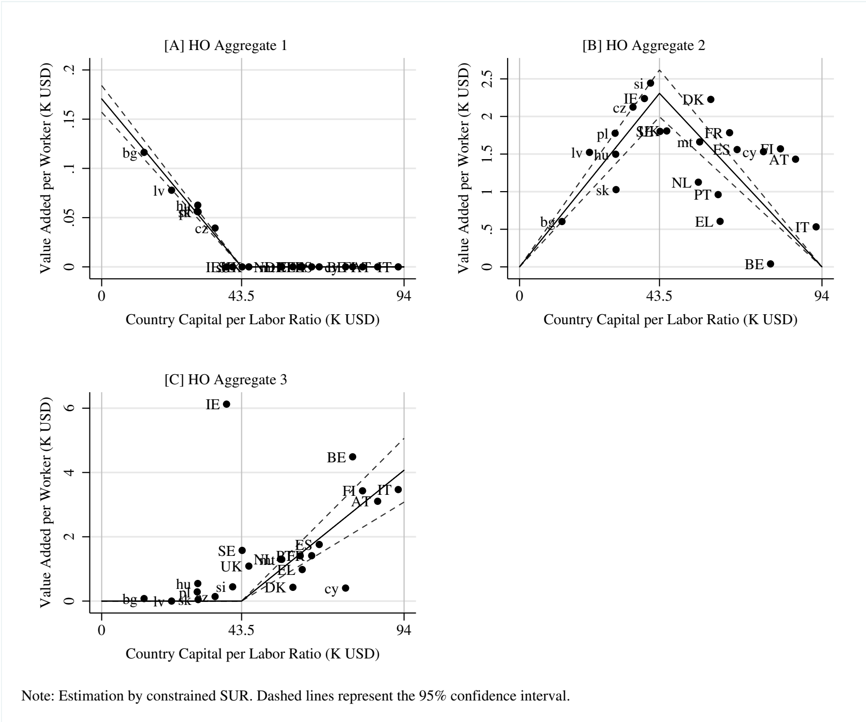


FIGURE 12. ESTIMATED DEVELOPMENT PATH FOR FAVORED TWO-CONE MODEL: 2003

Note: See notes of Figure 4

Hall, Robert E., and Charles I. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker Than Others? Author(s):." *Quarterly Journal of Economics*, 114(1): 83–116.

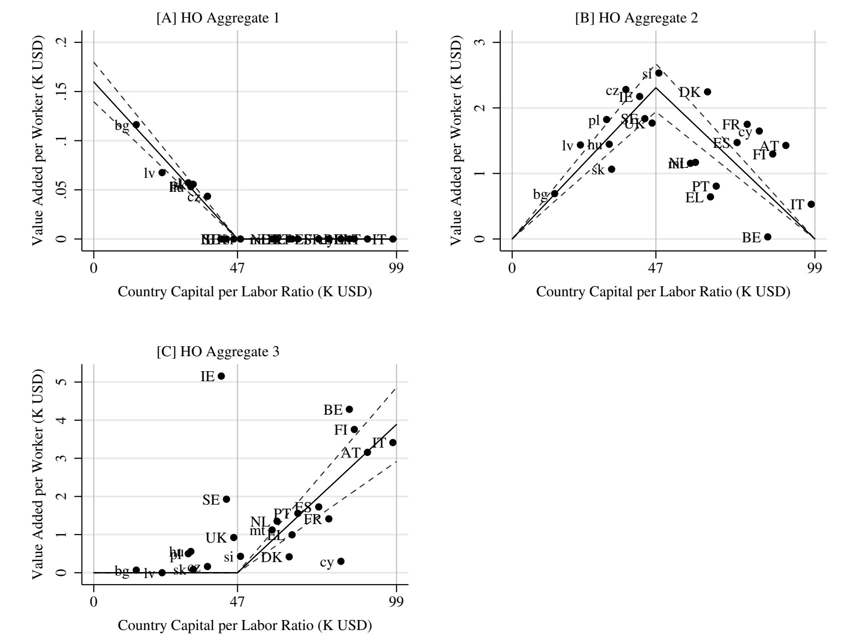
Harrigan, James. 1995. "Factor endowments and the international location of production: Econometric evidence for the OECD, 19701985." *Journal of International Economics*, 39(1-2): 123–141.

Harrigan, James. 1997. "Technology, Factor Supplies, and International Specialization: Estimating the Neoclassical Model." *American Economic Review*, 87(4): 475–494.

Kärkkäinen, Arja. 2008. "EU-15 Foreign Direct Investment in the new Member States." *Eurostat Statistics in Focus*, , (71).

Kiyota, Kozo. 2011. "Paths of development and wage variations." *Review of International Economics*, 19(4): 697–717.

Kiyota, Kozo. 2012. "A many-cone world?" *Journal of International Economics*, 86(2): 345–354.



Note: Estimation by constrained SUR. Dashed lines represent the 95% confidence interval.

FIGURE 13. ESTIMATED DEVELOPMENT PATH FOR FAVORED TWO-CONE MODEL: 2004

Note: See notes of Figure 4

Koren, Miklós, and Silvana Tenreyro. 2007. "Volatility and Development." *Quarterly Journal of Economics*, 122(1): 243–287.

Leamer, Edward E. 1987. "Paths of Development in the Three-Factor, n-Good General Equilibrium Model." *Journal of Political Economy*, 95(5): 961.

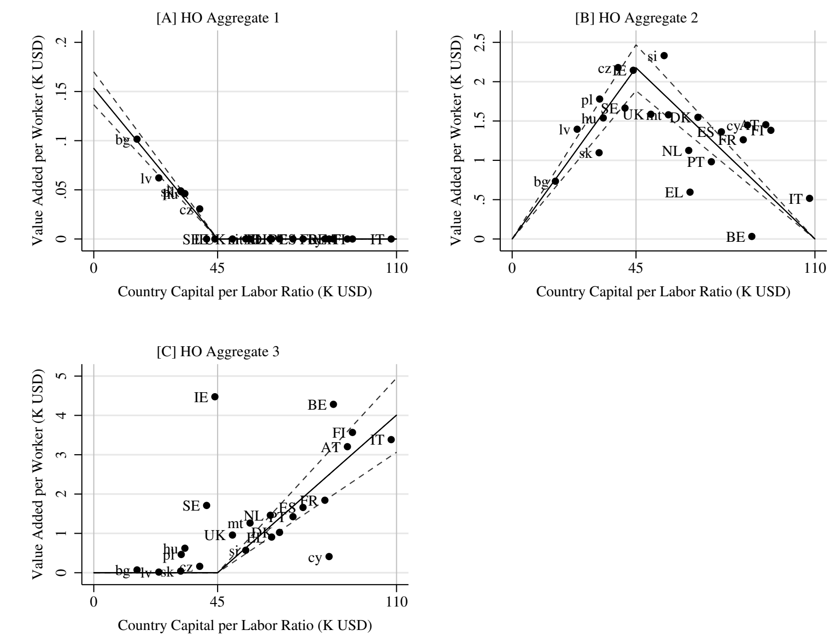
Leamer, Edward E. 1995. "The Heckscher-Ohlin Model in Theory and Practice." *Princeton Studies in International Finance*, , (77).

Leamer, Edward E., and James Levinsohn. 1995. "Chapter 26 International trade theory: The evidence." *Handbook of International Economics*, 3(C): 1339–1394.

Martincus, Christian Volpe, and Jennifer Pédussel Wu. 2005. "Economic Integration in a Multicone World." *ZEI Working Papers*, B07-2005: 0–22.

Melvin, J.R. 1968. "Production and trade with two factors and three goods." *The American Economic Review*, 58(5): 1249–1268.

Redding, Stephen. 2002. "Specialization dynamics." *Journal of International Economics*, 58(2): 299–334.



Note: Estimation by constrained SUR. Dashed lines represent the 95% confidence interval.

Figure 14. Estimated Development Path for Favored Two-Cone Model: 2005

Note: See notes of Figure 4

Reeve, Trevor A. 2006. "Factor endowments and industrial structure." *Review of International Economics*, 14(1): 30–53.

Schott, Peter K. 2003. "One size fits all? Heckscher-Ohlin specialization in global production." *American Economic Review*, 93(3): 686–708.

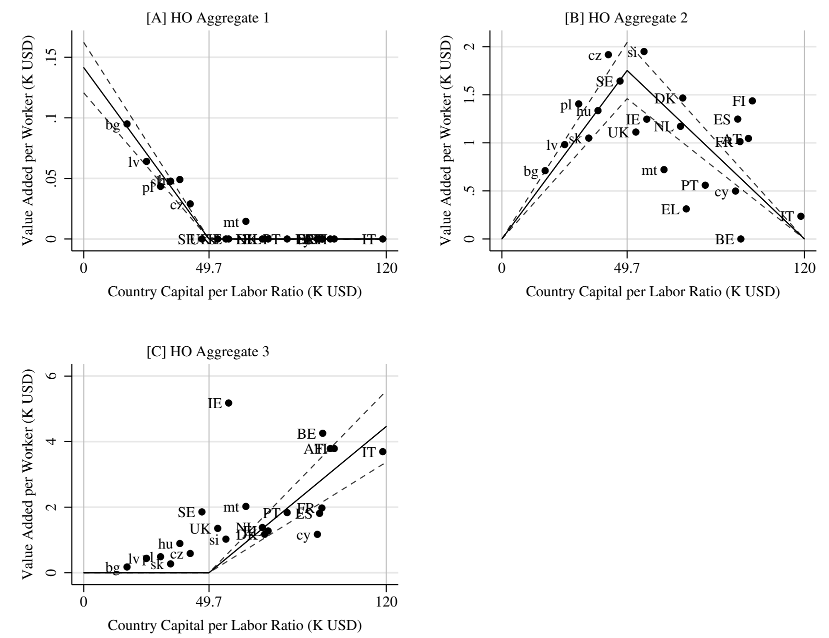
United Nation Industrial Development Organization. 2014. *Industrial Statistics Database at 2-Digit Level of ISIC Rev.3.* . CD-ROM ed.

Xiang, Chong. 2007. "Diversification cones, trade costs and factor market linkages." *Journal of International Economics*, 71(2): 448–466.

Statistical Appendix

A1. The Generalized R^2

For the T-cone model with $I = T + 1$ HO aggregats, I define the $C \times I$ matrix of dependent variables as $\mathbf{x}$ where C is the number of observations (equivalent to the number of countries). Mean deviance matrix of $\mathbf{x}$ can be expressed as



Note: Estimation by constrained SUR. Dashed lines represent the 95% confidence interval.

FIGURE 15. ESTIMATED DEVELOPMENT PATH FOR FAVORED TWO-CONE MODEL: 2006

Note: See notes of Figure 4

(A1)
$$\mathbf{x}_{dev} = \mathbf{x} - \mathbf{x} = \begin{bmatrix} x_{1,1} & x_{2,1} & x_{2,1} \\ x_{1,2} & x_{2,2} & x_{2,3} \\ \vdots & \vdots & \vdots \\ x_{1,C} & x_{2,C} & x_{2,C} \end{bmatrix} - \begin{bmatrix} \overline{x}_1 & \overline{x}_2 & \overline{x}_3 \\ \overline{x}_1 & \overline{x}_2 & \overline{x}_3 \\ \vdots & \vdots & \vdots \\ \overline{x}_1 & \overline{x}_2 & \overline{x}_3 \end{bmatrix},$$

with $\overline{x}$ is the $C \times I$ matrix of sample mean. Berndt (1991) defines the generalized variance of $\mathbf{x}$ as the determinant of $\mathbf{x}'_{dev}\mathbf{x}_{dev}$. By defining the $C \times I$ matrix of residuals by $\mathbf{e}$, the generalized R^2 is computed as,

(A2)
$$R^2 = 1 - \frac{\det(\mathbf{e}'\mathbf{e})}{\det(\mathbf{x}'_{dev}\mathbf{x}_{dev})}.$$

A2. Testing a Single-Cone Model against Multiple-Cone Model

1) Estimate a null-hypothesis of single-cone model using two HO aggregates. HO aggregate i in country c is constructed by, $X_{ic}^{H_0} = \sum_{k_{nc} \in \left(h_{i-1}^{H_0}, h_i^{H_0}\right]} Q_{nc}$ for $i = 1, 2$ and $h_0^{H_0} = 0$. After fitting the model, we compute share of ISIC industry n in HO aggregate i as $s_{inc} = Q_{nc}/X_{ic}^{H_0}$. I analogously estimate alternative T-cone model using $T+1$ HO aggregates, $X_{ic}^{H_1} = \sum_{k_{nc} \in \left(h_{i-1}^{H_1}, h_i^{H_1}\right]} Q_{nc}$ for $i \in (1, T+1)$ and $h_0^{H_1} = 0$. Because each model has different number of parameters, difference in Akaike's information criteria (AIC) between two models are utilized as relative fit measurement, $d = AIC^{H_0} - AIC^{H_1}$.

2) Assume the null hypothesis of the single-cone model to be true and compute a fitted value of HO aggregate using coefficient estimates in step 1) as $\hat{X}_{ic}^{H_0} = \hat{\boldsymbol{\beta}'}_i^{H_0} \mathbf{V}_c + \hat{\varepsilon}_i^{H_0}$, where $\hat{\boldsymbol{\beta}}$ isvector of estimated coefficients, $\mathbf{V}$ represents regressors in equation (*), and $\hat{\varepsilon}_i^{H_0}$ is distributed normally with mean zero and standard deviation equal to the root mean squared error of the HO aggregate i regression.

3) Use the drawn country-HO aggregate outputs to compute country-ISIC industry outputs as, $\hat{Q}_{nc} = s_{nc} \hat{X}_{ic}^{H_0}$.

4) Use the vector of country-ISIC industry output $\hat{\boldsymbol{Q}}$ to estimate a single- model and the alternative multiple-cone model. The same capital intensity cutoffs and knot locations obtained in step 1) are applied. Compute the test statistics.

5) Repeat 2 through 4 to create a confidence interval and compare the relative fit in step 1) to this interval.