No. 2287

THE DYNAMICS OF INTERNATIONAL SPECIALIZATION

Stephen Redding

INTERNATIONAL TRADE

Centre for Economic Policy Research

ISSN 0265-8003

THE DYNAMICS OF INTERNATIONAL SPECIALIZATION

Stephen Redding, London School of Economics and CEPR

Discussion Paper No. 2287
November 1999

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: http://www.cepr.org

CEPR Discussion Paper No. 2287

November 1999

ABSTRACT

The Dynamics of International Specialization*

The theoretical literature on trade and growth suggests that comparative advantage is endogenous and evolves over time. However, most of the empirical analysis of international trade flows is essentially static in nature. This Paper proposes an empirical model of the dynamics of international specialization. Employing disaggregated data on 20 industries in 7 OECD countries, we examine the evolution of patterns of international specialization over time and evaluate the role of changes in factor endowments in explaining observed dynamics.

JEL Classification: C14, F11, F14
Keywords: distribution dynamics, factor endowments, international trade, neoclassical model

Stephen Redding
Department of Economics
London School of Economics,
Houghton Street,
London WC2A 2AE
UK
Tel: (44 171) 955 7483
Fax: (44 171) 831 1840
E-mail: s.j.redding@lse.ac.uk

* I am very grateful to Richard Baldwin, Simon Evenett, Rachel Griffith, Gordon Hanson, James Harrigan, Wolfgang Keller, Peter Neary, Steve Nickell, Victor Norman, Henry Overman, James Proudman, Danny Quah, Jonathan Temple, Tony Venables, Alan Winters; participants in seminars at the London School of Economics, the CEPR European Research Workshop in International Trade (ERWIT), the Tilburg Conference on Dynamics, Economic Growth and International trade (DEGIT) and the World Bank for most helpful comments and suggestions. I would like to thank Mercedes Vera-Martin and Paco Requena-Silvente for excellent research assistance. I am extremely grateful to John Van Reenen for supplying the skills data. The support of the Centre for Economic Performance, London School of Economics is gratefully acknowledged. Any opinions, results, and errors are the responsibility of the author alone.

Submitted 29 September 1999

NON-TECHNICAL SUMMARY

Much of the existing empirical trade literature is concerned with explaining patterns of international trade at a point in time. The main body of empirical research over the last 15 years has examined the predictions of the Heckscher-Ohlin-Vanek model for cross-country trade in factor services. While much has been learnt about the determinants of international trade, the empirical literature's focus on the static predictions of trade theory contrasts markedly with the recent theoretical literature on trade and growth. This emphasizes that comparative advantage is dynamic; patterns of international trade evolve over time as innovations occur and factor endowments change.

This Paper proposes an empirical framework for analysing the evolution of international specialization over time. We address four main sets of issues relating to the dynamics of trade patterns. The first is concerned with changes in the overall degree of international specialization: do we observe countries increasingly specializing in certain subsets of industries? The second set of issues relates to how a country's extent of specialization in *individual* sectors changes over time: if country c specializes in industry j at time t, what is the probability that country c continues to specialize in the industry at time $t+x$, $x \geq 1$? Are countries' initial patterns of international specialization locked-in over time, or do we observe substantial reversals over time?

The third set of issues centres on the long-run or steady-state implications of observed changes in international specialization. For example, if each country is increasingly specializing in a subset of industries, what does this imply for the future pattern of world production and trade? The fourth set of issues concerns the structural economic determinants of changes in international specialization. For example, if countries' initial patterns of specialization are locked-in over time, is this due to the nature of technological progress or is it explained by factor accumulation?

This Paper largely concentrates on the second and fourth sets of issues above: the extent to which initial patterns of international specialization persist over time and the economic forces underlying changes in specialization. We begin by deriving an empirical measure of a country c 's extent of specialization in an individual sector j at time t directly from neoclassical trade theory. This measure is the share of the sector in a country's GDP. A country's pattern of international specialization at any one point in time is fully described by the distribution of the theory-consistent measure across industries. The dynamics of patterns of international specialization correspond to the evolution of the entire cross-section distribution over time. We employ a model of distribution dynamics that is explicitly suited to an analysis of evolving distributions. Within a single conceptual framework, we are able to address all four of the dynamic issues identified above.

The framework is implemented empirically using data on 20 manufacturing industries in 7 OECD countries. We begin by pooling country-industry-year observations and estimating transition probability matrices using data on shares of GDP. These reveal substantial mobility in patterns of international specialization over time and the extent of mobility as opposed to persistence is quantified using formal indices of mobility. Stochastic kernels are also estimated on the pooled country-industry-year data; these again reveal substantial mobility in patterns of international specialization over time.

Neoclassical trade theory identifies a structural economic relationship between the share of a sector in GDP on the one hand and factor endowments, technology parameters and relative goods prices on the other. We examine the extent to which changes in countries' factor endowments can explain evolving patterns of international specialization. First, within groups, estimation is used to decompose the variation in our empirical measure of specialization into the part explained by differences in factor endowments and the part explained by technology and relative goods prices. Second, transition probability matrices and stochastic kernels are estimated using data on the share of sector j in country c's GDP predicted from factor endowments alone.

The regression results reveal factor endowments to be an important determinant of patterns of international specialization. Of the 100 industry-specific coefficients on the 5 factor endowments considered, 77 are statistically significant at the 5% level. Again, we begin by pooling country-industry-year observations. The transition probability matrices estimated using the data on predicted values are in general characterised by larger diagonal and smaller off-diagonal terms. That is, there is greater persistence in the distribution of predicted values for shares of GDP than in the distribution of observed values. This finding is confirmed using formal indices of mobility.

The hypothesis that the data generation process (DGP) for predicted values is the matrix of transition probabilities estimated for observed shares of GDP is rejected at the 1% level. Stochastic kernels are also estimated using the pooled country-industry-year data and again reveal greater persistence in the distribution of predicted values. The increase in persistence is greatest at high and low values for industry shares of GDP. As a final robustness test, we allow for cross-country differences in the dynamics of international specialization. Transition probability matrices are estimated at the level of individual countries and confirm the earlier results using pooled country-industry-year data.

In conclusion, the Paper presents an empirical framework for analysing the dynamics of international specialization. A theory-consistent measure of specialization is derived from neoclassical trade theory. Within a single conceptual framework, four sets of issues are addressed: changes in the overall degree of international specialization, persistence versus mobility, implications for long-run patterns of specialization and the role of changing factor endowments. Using data on 20 manufacturing industries in 7 OECD countries, we find substantial mobility in patterns of international specialization over time. The extent of mobility is greater than would be predicted on the basis of countries' factor endowments alone. Factor endowments are found to be a source of persistence rather than mobility in patterns of international specialization.

1 Introduction

Much of the existing empirical trade literature is concerned with explaining patterns of international trade at a point in time. The main body of empirical research over the last 15 years has examined the predictions of the Heckscher-Ohlin-Vanek model for cross-country trade in factor services. While much has been learnt about the determinants of international trade, the empirical literature's focus on the static predictions of trade theory contrasts markedly with the recent theoretical literature on trade and growth. This emphasises that comparative advantage is dynamic; patterns of international trade evolve over time as innovations occur and factor endowments change.

This paper proposes an empirical framework for analysing the evolution of international specialisation over time. We address four main sets of issues relating to the dynamics of trade patterns. The first is concerned with changes in the overall degree of international specialisation: do we observe countries increasingly specialising in certain subsets of industries? The second set of issues relates to how a country's extent of specialisation in *individual* sectors changes over time: if country c specialises in industry j at time t, what is the probability that country c continues to specialise in the industry at time $t + x$, $x \geq 1$? Are countries' initial patterns of international specialisation locked-in over time, or do we observe substantial reversals over time?

The third set of issues centres on the long-run or steady-state implications of observed changes in international specialisation. For example, if each country is increasingly specialising in a subset of industries, what does this imply for the future pattern of world production and trade? The fourth set of issues concerns the structural economic determinants of changes in international specialisation. For example, if countries' initial patterns of specialisation are locked-in over time, is this due to the nature of technological progress or is it explained by factor accumulation?

Each set of issues is suggested by the theoretical literature on trade and growth, and yet each is a subject upon which existing empirical work has relatively little to say. This paper will largely concentrate on the second and fourth sets of issues identified above - the extent to which initial patterns of specialisation persist over time and the economic forces underlying changes in international specialisation. In the theoretical literature, Krugman (1987), Lucas (1988), and Redding (1999) present Ricardian models in which a combination of sector-specific learning by doing and imperfect international knowledge spillovers results in initial patterns of specialisation becoming locked-in over time. There is persistence in observed patterns of international specialisation, and the nature of technological progress provides the explanation. In contrast, Davis and Reeve (1997), Deardorff (1974), and Findlay (1970), (1995) present modified Heckscher-Ohlin models, in which factor accumulation explains changes in international specialisation over time. In the $2 \times 2 \times 2$ Heckscher-Ohlin model, initial patterns of international specialisation may either be locked-in or reversed over time, depending upon whether the capital-abundant or capital-scarce country exhibits the more rapid increase in the ratio of capital to labour endowments.

The starting point for the analysis in this paper is the general neoclassical model of trade, as expounded by Dixit and Norman (1980), Harrigan (1997), and Woodland (1982). An empirical measure of a country c's extent of specialisation in a sector j at time t is derived directly from neoclassical trade theory: the share of the sector in country c's GDP. A country's pattern of international specialisation at a point in time is fully described by the distribution of the theory-consistent measure across sectors. The dynamics of international specialisation correspond to the evolution of the entire cross-section distribution over time. We employ a model of distribution dynamics first introduced into the literature on cross-country income convergence by Quah (1993), (1996a), (1996b), and (1997a), and which is explicitly suited to analysing the evolution of an entire distribution.

The first three sets of issues identifed above are concerned with changes in observed values for our empirical measure of specialisation. They are directly addressed by the application of these statistical techniques; we estimate transition probability matrices and stochastic kernels using data on the share of sector j in country c's GDP. The fourth set of issues relates our empirical measure of specialisation to its economic determinants. Neoclassical trade theory identifies a structural relationship between the share of a sector in GDP on the one hand, and factor endowments, technology parameters, and relative goods prices on the other. This paper examines the extent to which changes in countries' factor endowments explain the evolution of observed patterns of international specialisation. The analysis proceeds in two stages. First, we decompose the variation in our empirical measure of specialisation into the component explained by differences in factor endowments and the component explained by technology and relative goods prices. Second, we estimate transition probability matrices and stochastic kernels using data on the share of sector j in country c's GDP predicted from countries' factor endowments.

The empirical framework outlined above is implemented using data on 20 manufacturing industries in 7 OECD countries. We begin by pooling country-industry-year observations and estimating transition probability matrices using data on observed shares of GDP. These reveal substantial mobility in patterns of international specialisation over time; the extent of mobility as opposed to persistence is quantified using formal indices of mobility. Within groups estimation shows factor endowments to be an important determinant of international specialisation. Of the 100 industry-specific coefficients on the 5 factor endowments considered, 77 are statistically significant at the 5% level. From the results of the within groups estimation, we derive the values for sectoral shares of GDP predicted from countries' factor endowments.

Transition probability estimation using the data on predicted shares of GDP reveals greater persistence than for the distribution of observed shares of GDP. That is, observed patterns of international specialisation display substantially more mobility than would be predicted on the basis of factor endowments alone. Factor endowments are a source of persistence rather than mobility in patterns of international specialisation over time. The hypothesis that the data generation process (DGP) for the predicted values is actually the matrix of transition probabilities estimated for observed shares of GDP is rejected at the 1% level.

Two extensions to the analysis are considered. First, we continue to pool country-industry-year observations, but estimate stochastic kernels. These map each value of either observed or predicted shares of GDP at time t into all other values at time $t + x$, $x \geq 1$. The finding that factor endowments are a source of persistence is confirmed, with the increase in the degree of persistence greatest at high and low values for shares of GDP. Second, we allow for cross-country heterogeneity in the stochastic process determining the evolution of international specialisation over time by estimating transition probability matrices at the level of individual countries. Again, the finding that factor endowments are a source of persistence is confirmed.

The remainder of the paper is structured as follows. Section 2 reviews the relationship to the existing literature. Section 3 derives an empirical measure of international specialisation from neoclassical trade theory and relates it to structural economic determinants. Section 4 introduces the model of distribution dynamics, while Section 5 undertakes a preliminary analysis of the data. Section 6 presents the results of the econometric estimation; Section 7 summarises our conclusions.

2 Relation to Existing Literature

For the last 15 years, the dominant paradigm for the empirical modelling of international trade flows has been the generalised factor proportions model of trade with n goods and m factors.[1] It is useful to distinguish two main strands of empirical research within this paradigm. The first analyses the model's predictions for countries' net trade in factor services (the so-called Heckscher-Ohlin-Vanek (HOV) model); important contributions include those of Bowen *et al.* (1987), Davis *et al.* (1997), Davis and Weinstein (1998), Gabaix (1997), Leamer (1984), and Trefler (1995). The second strand of empirical research begins with Harrigan (1995) and examines the model's predictions for the international location of production (see also Bernstein and Weinstein (1998) and Hanson and Slaughter (1999)). In its strictest form, the generalised factor proportions model of trade assumes identical preferences and identical technologies across countries, although much research effort has been devoted to relaxing these assumptions: see for example Davis and Weinstein (1998).

The factor proportions model of trade is in fact a special case of the more general neoclassical model: see in particular Dixit and Norman (1980) and Woodland (1982). Within neoclassical theory, patterns of international specialisation are jointly determined by cross-country differences in technologies, endowments, and preferences. Harrigan (1997) implements the neoclassical model empirically using data on 7 manufacturing industries in 10 OECD countries, and finds evidence that technology differences play a role alongside relative factor endowments in determining patterns of international specialisation. Harrigan and Zakrajsek (1999) employ a similar framework to examine the role of factor endowments in explaining international specialisation across a large number of developed and developing countries.

[1] A seminal early contribution is Leamer (1984). For recent surveys of the empirical trade literature, see Helpman (1999), Leamer and Levinsohn (1995), and Leamer (1999).

Some of these studies employ panel data estimation techniques, but each is essentially concerned with the static predictions of international trade theory for cross-section patterns of international specialisation at a point in time. The empirical literature's focus on the static predictions of international trade theory contrasts markedly with recent theoretical work on trade and growth. This emphasises that comparative advantage is dynamic and evolves endogenously over time. Early theoretical papers by Findlay (1970) and Deardorff (1974) analysed the implications of factor accumulation for patterns of international specialisation within the factor proportions model of trade (see also Davis and Reeve (1997) and Findlay (1995)). Krugman (1987) presents a dynamic Ricardian model with a continuum of goods, while Eaton (1987) introduces the accumulation of land and capital into the specific factors model. The dynamic nature of comparative advantage has received renewed theoretical attention in the recent literature on endogenous growth and trade: see for example Grossman and Helpman (1991), Lucas (1988), Redding (1999), and Rivera-Batiz and Romer (1991).

Despite this growing body of theoretical work, there has been relatively little empirical study of the evolution of patterns of international trade over time. There has been some empirical work on changing patterns of international trade, largely within the context of the Heckscher-Ohlin-Vanek model. Balassa (1979) examines the change in comparative advantage with economic development using cross-section data on 36 countries in 1972. For each country, measures of Revealed Comparative Advantage (RCA) in individual manufacturing sectors are regressed against sector-specific measures of human and physical capital per worker.[2] Cross-country differences in the estimated coefficients on human and physical capital are then related to cross-country differences in endowments of human and physical capital.

Stern and Maskus (1981) estimate cross-*industry* regressions of US net

[2] Following Balassa (1965), Revealed Comparative Advantage (RCA) is defined as country c's share of world exports in sector j divided by country c's share of world exports of all goods.

exports against US factor endowments for each year during 1958-76, and examine how the coefficient on US factor endowments changes over time. The coefficient on unskilled labour is found to become substantially more negative during the sample period, and there is evidence that the Leontief Paradox no longer held for US trade in 1972. Maskus (1983) extends the analysis by pooling cross-section data over time and undertaking statistical tests for changes in the regression coefficients.

Bowen (1983) considers the implications of the changing international distribution of factor endowments for US comparative advantage using data on 34 countries for five years between 1963 and 1975. Cross-*country* regressions of net exports against factor endowments are estimated for the five separate years. The relative availability of skilled versus unskilled labour is found to be an important determinant of US comparative advantage; the coefficient on physical capital changes from being negative in the 1960s to positive and statistically significant in the 1970s.

Feenstra and Rose (1997) examine the dynamic predictions of the 'product lifecycle' hypothesis for cross-country export patterns. Countries with high rates of growth of income per capita and high levels of productivity are found to export commodities early in the product lifecycle. Amiti (1997), Kim (1995), and Ruhashyankiko (1999) analyse changes in countries' overall degree of international specialisation using summary statistics such as the standard deviation, measures of skewness, and the Gini coefficient. Amiti (1997) is concerned with the European Union; Kim (1995) uses United States data; Ruhashyankiko (1999) considers 160 developed and developing countries. None of these studies analyses the degree of persistence versus mobility in patterns of international specialisation or the role played by countries' changing factor endowments.

This paper argues that an economy's pattern of international specialisation at a point in time should be thought of in terms of an entire distribution across sectors, and that the dynamics of international specialisation correspond to the evolution of this distribution over time. We employ a model of distribution dynamics, first introduced into the cross-country growth literature by Quah (1993), (1996a), (1996b), and (1997a), and explicitly suited to an analysis of evolving distributions. Within a single conceptual framework, we are able to address all four of the dynamic issues identified above: changes in the overall degree of international specialisation, the extent to which initial patterns of specialisation are locked-in over time, implications for long-run patterns of specialisation, and the economic forces underlying the dynamics of patterns of specialisation.

Other studies that have employed related statistical techniques in an international trade setting are Brasili *et al.* (1999), Hinloopen and Marrewijk (1998), Proudman and Redding (1998), and Stolpe (1994). Brasili *et al.* (1999), Hinloopen and Marrewijk (1998), and Proudman and Redding (1998) measure international specialisation by Revealed Comparative Advantage (RCA), while Stolpe (1994) uses analogous measures defined in terms of production and patent data (the Hoover Index and Revealed Technological Advantage (RTA)).[3] One key contribution of the present paper over these other studies is that it employs a theory-consistent measure of international specialisation. This is derived directly from neoclassical trade theory, and the paper seeks to integrate statistical models of distribution dynamics with mainstream international trade theory. Since our empirical measure of specialisation is derived from theory, it can be directly related to structural economic determinants. A second key contribution of the paper is to examine the extent to which the evolution of patterns of international specialisation over time can be explained by changes in countries' factor endowments.

[3] The Hoover index is defined in the same way as RCA, but using value-added, employment, or production data: country c's share of world production in sector j divided by country c's share of world production of all goods (see for example Kim (1995)). Revealed Technological Advantage (RTA) is defined in the same way, but using data on research and development (R&D) expenditure or patents.

3 Theoretical framework

The starting point for the analysis is the standard neoclassical theory of trade, as expounded by Dixit and Norman (1980), Harrigan (1997), and Woodland (1982). Time is indexed by t, countries by $c \in \{1, ..., C\}$, final goods by $j \in \{1, ..., n\}$, and factors of production by $i \in \{1, .., m\}$. Each economy is endowed with an exogenous vector v_{ct} of factors of production. Production of each good is assumed to occur under conditions of perfect competition according to a constant returns to scale production function. We allow for differences in factor endowments across countries c and technology differences across both countries c and industries j.

We consider a small open economy, which by assumption faces an exogenous vector of world prices for final goods p_t. Producer equilibrium in the small economy may be represented in terms of the revenue function $r_c(p_t, v_{ct})$. Under the assumption that this function is twice continuously differentiable, the vector of the economy's profit-maximising net outputs $y_c(p_t, v_{ct})$ is equal to the gradient of $r_c(p_t, v_{ct})$ with respect to p_t.

If technology differences across countries, industries, and time are Hicks-neutral, the production function may be expressed as $y_{cjt} = \theta_{cjt}.F_j(v_{ct})$, where θ_{cjt} parameterises technology in industry j of country c at time t. In this case, the revenue function takes the form $r_c(p_t, v_{ct}) = r(\theta_{ct}.p_t, v_{ct})$, where θ_{ct} is an $n \times n$ diagonal matrix of the technology parameters θ_{cjt}.[4] Changes in technology in industry j of country c are modelled in exactly the same way as changes in the price of industry j output; the economy's vector of net outputs continues to be given by the gradient of the revenue function with respect to p_t.

We follow Harrigan (1997), Kohli (1991), and Woodland (1982) in assuming a translog revenue function; this flexible functional form provides an arbitrarily close approximation to the true underlying revenue function,[5]

[4] See Dixit and Norman (1980), pages 137-9.

[5] To save notation, we suppress the country-time subscripts except where important.

$$\ln r(\theta.p,v) = \alpha_{00} + \sum_j \alpha_{0j} \ln \theta_j p_j + \tfrac{1}{2} \sum_j \sum_k \alpha_{jk} \ln(\theta_j p_j) \ln(\theta_k p_k)$$
$$+ \sum_i \beta_{0i} \ln v_i + \tfrac{1}{2} \sum_i \sum_h \beta_{ih} \ln v_i . \ln v_h \qquad (1)$$
$$+ \sum_j \sum_i \gamma_{ji} \ln(\theta_j p_j) . (\ln v_i)$$

where $j,k \in \{1,...,n\}$ index goods and $i,h \in \{1,...,m\}$ index factors.

Symmetry of cross effects implies,

$$\alpha_{jk} = \alpha_{kj} \qquad \text{and} \qquad \beta_{ih} = \beta_{hi} \qquad \forall j,k,i,h \qquad (2)$$

Linear homogeneity of degree 1 in v and p requires,

$$\sum_j \alpha_{0j} = 1, \qquad \sum_i \beta_{0i} = 1, \qquad \sum_j \alpha_{kj} = 0 \qquad (3)$$

$$\sum_i \beta_{ih} = 0, \qquad \sum_i \gamma_{ji} = 0 \qquad (4)$$

Differentiating the revenue function with respect to each p_j, we obtain the following equation for the share of industry j in country $c's$ GDP at time t,

$$s_{cjt} = \frac{p_{cjt}.y_{cjt}(\theta_{ct}.p_{ct}, v_{ct})}{r(\theta_{ct}.p_{ct}, v_{ct})} = \alpha_{0j} + \sum_k \alpha_{jk} \ln p_{ckt} + \sum_k \alpha_{jk} \ln \theta_{ckt} + \sum_i \gamma_{ji} \ln v_{cit} \qquad (5)$$

If all goods are tradeable and goods prices are the same across countries ($p_{ckt} = p_{kt}$ for all c), the second term on the right-hand side of equation (5) may be replaced with a set of {0,1} time dummies (d_{jt}) for each industry j.[6] This paper evaluates the role of changing factor endowments in explaining the evolution of patterns of international specialisation. We estimate the following regression,

$$s_{cjt} = \alpha_{0j} + \phi_j . d_{jt} + \sum_i \gamma_{ji} \ln v_{cit} + u_{cjt} \qquad (6)$$

[6] See Harrigan (1997) for an extension to the case where some goods are nontradeable.

where u_{cjt} is a stochastic error. If country technology differences are neutral across sectors ($\theta_{cjt} = \mu_{ct}.\theta_{zjt}$ for all c, j and some reference country z) or if the country-industry technology parameters (θ_{cjt}) are uncorrelated with countries' factor endowments (v_{cit}), equation (6) will yield consistent estimates of the parameters γ_{ji}. Neutral technology differences affect levels of value-added but not shares of sectors in GDP (see Harrigan and Zakrajsek (1999)). Non-neutral technology differences will affect shares of sectors in GDP, but it is not at all clear how they will be correlated with countries' factor endowments. On the one hand, some authors argue that countries will be more productive in industries that employ their abundant factors intensively (see for example David (1975)). On the other hand, there are a large number of examples of countries which have high levels of productivity in certain industries and yet are scarce in the raw materials and factors of production that those industries use intensively (these include many manufacturing industries in Japan; see for example the discussion in Amsden (1989) and Porter (1990)).[7]

If country technology differences are both non-neutral across sectors and correlated with factor endowments, the estimated parameters $\hat{\gamma}_{ji}$ are inconsistent and do not have a structural interpretation. Nonetheless by construction, the residuals $\hat{u}_{cjt}$ will be orthogonal to the right-hand side variables and correspond to that part of the variation in shares of GDP that is statistically unexplained by countries' factor endowments and industry-time dummies (capturing relative prices). The explained sum of squares may be decomposed into the contributions of factor endowments and industry-time dummies. In this way, we may obtain that part of the variation in shares of GDP explained by countries' factor endowments,

[7] In fact, there is a theoretical literature arguing that natural resource abundance may have a negative effect on rates of technological progress (see for example Sachs and Warner (1995)).

$$\tilde{s}_{cjt} = \hat{\phi}_j + \sum_i \hat{\gamma}_{ji} \ln v_{cit} \tag{7}$$

Equation (6) may be estimated separately for each industry j using OLS, pooling observations across countries c and years t. Alternatively, we may pool observations across countries c, industries j, and years t and estimate the same relationship using within groups, where the fixed effect is for industry j and we allow all coefficients (on both the time dummies and countries' factor endowments) to vary across industries. Since within groups is Least Squares Dummy Variables, these two procedures yield identical parameter estimates.

Equation (6) is employed in two ways in the ensuing analysis. First, it identifies a theory-consistent measure of the extent of an economy c's specialisation in sector j: the share of that sector in GDP (s_{cjt}). The economy's pattern of international specialisation at a point in time corresponds to the distribution of shares of GDP across sectors, while the dynamics of international specialisation relate to the evolution of the entire distribution of shares of GDP over time. Second from equation (6), we obtain that part of the variation in shares of GDP explained by countries' factor endowments (equation (7)). This corresponds to a set of predicted values for industry shares of GDP from countries' factor endowments. The evolution of the entire distribution of these predicted values reveals the contribution of factor endowments to changing patterns of international specialisation. The next section introduces the formal model of distribution dynamics that will be used to analyse the evolution of both observed shares of GDP and the values predicted from countries' factor endowments.

4 Distribution Dynamics

Denote the Borel-measurable set of possible values for shares of GDP (s) by A. The distribution of s across countries c and industries j at time t is denoted by $F_t(s)$. Corresponding to F_t, we may define a probability measure λ_t where $\forall\ s \in \Re$, $\lambda_t((-\infty, s]) = F_t(s)$. Following Quah (1993), (1996a), and (1996b) the evolution of the cross-section distribution of s over time is modelled in terms of a stochastic difference equation,

$$\lambda_t = P^*(\lambda_{t-1}, u_t), \qquad \text{integer } t \tag{8}$$

where $\{u_t : \text{integer } t\}$ is a sequence of disturbances and P^* is an operator that maps disturbances and probability measures into probability measures. For simplicity, we assume that this stochastic difference equation is first-order and that the operator P^* is time invariant. Absorbing the disturbance u_t into the definition of the operator Z^* (see Quah (1997a)), we obtain,

$$\lambda_t = Z^*(\lambda_{t-1}), \qquad \text{integer } t \tag{9}$$

If the set A of possible values for s is divided into a number of discrete cells, Z^* becomes a matrix of transition probabilities, which may be estimated by counting the number of transitions out of and into each cell (see for example Quah (1993) and Proudman and Redding (1998)). Alternatively with a sufficiently large number of country-industries, it is possible to analyse the evolution of continuous probability measures (see for example Quah (1996b), (1997a)). The evolution of λ_{t-1} to λ_t is fully described by the stochastic kernel or mapping M_{t-1} to $[0,1]$ such that,

$$\forall \text{ Borel-measurable } A: \qquad \lambda_t(A) = \int M_{t-1}(s, A).d\lambda_{t-1}(s) \tag{10}$$

where M_{t-1} may be estimated nonparametrically using kernel density estimation techniques.

Whether working with discrete or continuous probability measures, these techniques explicitly analyse the evolution of the entire distribution of shares of GDP over time. In so doing, they shed light on four sets of economic issues relating to the dynamics of international specialisation. The first set of issues concerns how the degree of international specialisation is changing over time; this corresponds to the evolution of the *external shape* of the distribution of shares of GDP (s) across sectors. For example, are economies increasingly specialising in certain subsets of industries? If so, one would expect to observe the distribution of s polarising at extreme values, a development that will not necessarily be revealed by an analysis of statistics such as the standard deviation or coefficient of skewness.

The second set of issues is concerned with how the pattern of international specialisation across individual sectors is changing over time. This corresponds to the movement of individual sectors within the distribution of s or *intra-distribution dynamics*. For example, are the sectors with high values of s the same at times t and $t+x$ (where $x \geq 1$)? Do initial patterns of international specialisation persist or become locked-in over time? Alternatively, does one observe reversals in initial patterns of international specialisation? This paper provides an empirical evaluation of the extent of persistence and mobility in patterns of international specialisation: the transition probability matrix or the mapping M_{t-1} reveal the extent of mobility and persistence throughout the entire distribution of s.

The third set of issues relates to the long-run properties of the distribution of s. Iterating equation (9) forwards in time yields a predictor for future cross-section distributions of s,

$$\begin{aligned} \lambda_{t+\tau} = Z^*(\lambda_{t+\tau-1}) &= Z^*(Z^*(\lambda_{t+\tau-2})) \\ &\vdots \\ &= Z^*(Z^*(Z^* \ldots (Z^*(\lambda_t)) \ldots)) \\ &= (Z^*)^\tau \lambda_t \end{aligned} \tag{11}$$

Taking the limit as τ becomes arbitrarily large yields information concerning the long-run distribution of s. For example, if the economy is increasingly specialising in subsets of industries as suggested above, $\lambda_{t+\tau}$ will tend towards a bimodal measure. Alternatively, if the degree of international specialisation is declining over time, $\lambda_{t+\tau}$ will tend towards a more uniform distribution. If we divide the set of possible values for s into a number of discrete cells and estimate a transition probability matrix, the ergodic or stationary distribution of s as $\tau \to \infty$ is given by the eigenvector corresponding to largest eigenvalue of the transition probability matrix.

The fourth set of issues concerns the structural economic determinants of observed changes in international specialisation. Motivated by the theoretical literature dating back to Findlay (1970) and Deardorff (1974), this paper analyses the role of changing factor endowments in explaining the dynamics of patterns of international specialisation. The statistical techniques exposited above are applied to both the distribution of observed shares of GDP and the distribution of shares of GDP predicted from countries' factor endowments. The analysis of the latter is related to the conditioning exercises undertaken in the cross-country growth literature by Quah (1996b) and (1997b).

In the discussion so far, we have implicitly assumed a common distribution function for s across all countries ($F_{ct}(s) = F_t(s)$ and $\lambda_{ct} = \lambda_t$ for all c) and a common stochastic process governing the evolution of the probability measure λ_t over time ($Z^*_c(\cdot) = Z^*(\cdot)$ for all c). Under this assumption, observations on s may be pooled across countries and industries, and a single transition probability matrix or stochastic kernel may be estimated. The framework may also be extended to allow for cross-country heterogeneity in the stochastic process determining the dynamics of international specialisation ($\lambda_{ct} = Z^*_c(\lambda_{ct-1})$, where $Z^*_c(\cdot) \neq Z^*_b(\cdot)$ for some countries c and b). In the empirical analysis that follows, we not only pool country-industry observations and estimate a single transition probability matrix, but also estimate transition probability matrices on industry observations separately for each country.

5 Preliminary Data Analysis

The theoretical approach developed above is implemented empirically using data on twenty manufacturing industries in seven OECD countries during 1970-90. Industry-level data on current price value-added are taken from the OECD's Structural Analysis Industrial (STAN) database, while current price GDP data come from the Penn World Tables 5.6. Endowments of five factors of production are considered: durable goods capital, other capital, arable land, skilled labour, and unskilled labour. The data on both categories of capital goods are from the Penn World Tables 5.6, while the source of data on hectares of arable land is the United Nations Food and Agricultural Organisation.

Endowments of skilled and unskilled labour are measured using data on the proportion of non-production and production workers in total manufacturing employment from the United Nations General Industrial Statistics Database (UNISD).[8] We follow a number of authors in using data on non-production and production workers to measure of skills: see in particular Berman, Bound and Machin (1998) and Lawrence and Slaughter (1993). A key advantage of these data over the educational attainment information in Barro and Lee (1993) is that they are available on an annual basis.[9] The choice of countries reflects the availability of the UNISD data. Our sample includes Canada, Denmark, Finland, Japan, Sweden, the United Kingdom, and the United States, a group of countries among which one would expect to observe substantial differences in both patterns of specialisation and factor endowments. We consider twenty disaggregated manufacturing industries; see Appendix C for further details concerning the data used and

[8] These data were supplied by John Van Reenen: see Berman, Bound, and Machin (1998) and Machin and Van Reenen (1998) for further discussion of the data used.

[9] See Appendix B for a comparison of occupation and education-based measures of skills in the United Kingdom and United States.

an industry concordance.

Table 1 reports the share of total manufacturing value-added in GDP and the share of each industry's value-added in total manufacturing for all seven countries in 1970 and 1990. Manufacturing's share of GDP declines in all countries during the sample period, although the rate of decline between 1970 and 1990 varies substantially across countries: from 30.6% in the United Kingdom to 10.1% in Denmark. The initial level of manufacturing's share of GDP also shows substantial variation: from 17.4% in Denmark to 36.7% in Japan.

<Table 1 about here>

Table 1 reveals marked changes in the relative importance of individual sectors within manufacturing. Some sectors account for a declining share of manufacturing value-added in all countries (eg Textiles and Ferrous Metals), while others constitute a rising share of manufacturing value-added in all countries (eg Drugs and Radio/TV). Again, the rate of decline or increase varies noticeably across countries: for example in Radio/TV, the rate of increase varies from 19.8% between 1970 and 1990 in the United Kingdom to 62.5% in Japan and 297.6% in Finland. There are also examples of sectors which account for rising shares of manufacturing value-added in some countries and declining shares in others: for example, the share of the Computing sector displays a rapid increase in all countries except Canada and Sweden where it declines by 37.3% and 52.8% respectively between 1970 and 1990.

Table 2 evaluates factor endowments in the seven countries in 1970 and 1990. Bowen *et al.* (1987) and Bowen *et al.* (1998) propose the following definition of *relative factor abundance*: factor i is abundant *relative* to factor h in country c if country c's world share of factor i exceeds its world share of factor h. Under the assumptions of the Heckscher-Ohlin-Vanek model (a special case of the neoclassical model, with identical technologies and preferences), it is true that if a country c is abundant in factor i relative to factor h, then its proportionate net trade in the services of factor i will exceed its proportionate net trade in the services of factor h.[10]

<Table 2 about here>

In the present case, we employ relative factor abundance as one measure of countries' changing factor abundance; world factor endowments are defined in terms of the sum of the seven countries. For comparison, Table 2 also reports countries' shares of world GDP, where world GDP is defined similarly. There are substantial variations in relative factor abundance across economies. Japan is the only economy where non-production workers are abundant relative to production workers; Canada's share of world durable capital in 1970 is less than half its share of world other capital, while the United Kingdom's share world durable capital in 1970 is more than double its share of world other capital. There are also changes in relative factor abundance over time. For example, Japan's share of world durable capital rises substantially between 1970 and 1990. In 1970, production workers were abundant relative to durable capital in Japan; by 1990, this initial pattern of relative factor abundance had been reversed.

Changes in countries' endowments of factors of production will only be important in explaining the dynamics of international specialisation if there are differences in factor intensity across industries. Industry-level data on the number of production and non-production workers and the quantity of physical capital employed are not available at the level of sectoral disaggregation used in Table 1. Nonetheless, it is possible to obtain some information on factor intensity if we aggregate to the two and three-digit level, although we are unable to distinguish between different categories of physical capital. Table 3 reports the average number of production and non-production workers employed per million dollars of value-added and the average quantity of physical capital employed per dollar of value-added in the United States

[10] Proportionate net trade in a factor i is country c's net trade in factor i divided by either country c's total supply of factor i or the world supply of factor i. An alternative definition of *absolute* factor abundance also exists: see Bowen *et al.* (1998).

during 1970-90. There are substantial differences in factor intensity across sectors: for example, the intensity of use of non-production workers varies from 4.8 in Primary Metals (ISIC 37) to 12.1 in Professional Goods (ISIC 385), while the intensity of use of production workers varies from 13.1 in Chemicals (ISIC 35) to 49.0 in Textiles/Apparel (ISIC 32). In the presence of factor price equalisation and if all countries had the same production technology in each sector, factor intensities would be the same in all countries.[11] More generally, they will vary both across industries and countries.

<Table 3 about here>

6 Econometric Estimation

Having informally examined changes in international specialisation and countries' factor endowments, this section moves on to estimate the model of distribution dynamics introduced above. We begin by analysing the evolution of the distribution of observed values for our theory-consistent measure of international specialisation: the share of sector j in country c's GDP (s_{cjt}). At first, we pool industry-year observations across all countries and divide the space of possible values for s into five discrete grid cells. Cell boundaries are chosen such that country-industry-year observations are divided roughly equally between cells, and we estimate transition probabilities over five-year time periods using Danny Quah's TSRF econometrics package.[12]

The upper panel of Table 4 reports the estimated matrix of transition probabilities; the interpretation of the table is as follows. The numbers in parentheses in the first column are the total number of country-industry-year observations beginning in a particular cell, while the first row of numbers denotes the upper endpoint of the corresponding grid cell. Thereafter, each row denotes the estimated probability of passing from one state into an-

[11] Much of the existing empirical literature on the Heckscher-Ohlin-Vanek model takes this case as its starting point.

[12] Responsibility for any results, opinions and errors is of course solely the author's.

other. For example, the second row of numbers presents (reading across from the second to the sixth column) the probability of remaining in the lowest state and then the probability of moving into the lower-intermediate, intermediate, higher-intermediate, and highest state successively. The final row of the upper panel of the table gives the implied ergodic distribution.

The extent of mobility in patterns of international specialisation is reflected in the relative magnitude of the diagonal and off-diagonal elements of the transition probability matrix. We find evidence of some mobility in patterns of international specialisation: for example, the probabilities of transiting out of the intermediate and higher-intermediate grid cells after five years are 0.27 and 0.30 respectively. Iterating the five-year transition probability matrix twice, the implied probabilities of remaining in these grid cells after 15 years are 0.46 and 0.40 respectively.

<Table 4 about here>

In order to evaluate the role of country factor endowments in explaining international specialisation at a point in time, equation (6) is estimated, including a full range of industry fixed effects and year-industry dummies. The results are presented in Table A1 of Appendix A. Factor endowments are found to be important determinant of international specialisation. Taking all industries together, 77 out of the 100 industry-specific coefficients on the five factor endowments are statistically significant at the 5% level. From the parameter estimates in Table A1, we derive that component of shares of GDP explained by differences in countries' factor endowments: shares of GDP predicted from countries' factor endowments (equation (7)).

The middle panel of Table 4 reports the estimated matrix of transition probabilities for the predicted values. In general, the matrix is characterised by larger diagonal and smaller off-diagonal terms, implying greater persistence in the distribution of predicted values than in the distribution of observed shares of GDP. Iterating the five-year transition probability matrix twice, the differences in mobility become more stark. The implied probabilities of remaining in the intermediate and higher-intermediate grid cells after 15 years are 0.58 and 0.49 respectively.

Factor endowments are thus found to be a source of persistence rather than mobility in observed patterns of international specialisation. In order to evaluate the degree of mobility in the two transition probability matrices more formally, the lower panel of Table 4 reports the values of three indices of mobility, each of which seeks to reduce information about mobility from the matrix of transition probabilities Z^* to a single statistic. Thus, M_1 (following Shorrocks (1978)) evaluates the trace (tr) of the matrix; M_2 (following Geweke *et al.* (1986) and Quah (1996c)) is based on the eigenvalues ξ_x of the matrix; M_3 (see Shorrocks (1978)) evaluates the determinant (det).[13] These indices confirm the finding of greater persistence in the distribution of predicted values for shares of GDP.

To obtain information concerning the statistical significance of the differences in the estimated transition probabilities, we make use of results relating to the asymptotic properties of first-order Markov Chains in Anderson and Goodman (1957). For each state k under the null hypothesis $p_{kl} = \tilde{p}_{kl}$,

$$\sum_{l=1}^{m} n_{k\cdot}^{*} \frac{(p_{kl} - \tilde{p}_{kl})^2}{\tilde{p}_{kl}} \sim \chi^2(m-1), \qquad n_k^* \equiv \sum_{t=0}^{T-1} n_k(t) \tag{12}$$

where p_{kl} are the estimated transition probabilities, $\tilde{p}_{kl}$ are the probabilities of transition under the (known) null and $n_k(t)$ denotes the number of sectors in cell k at time t.

This test statistic may be used to test the hypothesis that the transition probabilities estimated for the distribution of predicted values are the result of a Data Generation Process (DGP) given by those estimated for observed shares of GDP. The test may be undertaken for each state $k = 1, ..., m$; since

[13] For the exact relationship between these indices and the circumstances under which they yield transitive rankings of transition probability matrices see Shorrocks (1978) and Geweke *et al.* (1986).

the transition probabilities are independently distributed across states, we may sum over states and test the hypothesis that, for *all* states k, the estimated transition probabilities are equal to those under the null. The resulting test statistic is asymptotically distributed $\chi^2(m(m-1))$. The value of the χ^2 statistic derived from Table 4 is 55.26, and the null hypothesis is thus rejected at the 1%.

Throughout the analysis so far, the dynamics of international specialisation have been analysed by dividing the set of possible values for s into discrete cells and estimating transition probability matrices. It is also possible to analyse the evolution of continuous probability measures λ_t defined over s by estimating the stochastic kernel mapping λ_{t-1} to λ_t. Figure 1 presents a three-dimensional graph of the stochastic kernel for the distribution of observed shares of GDP (s), allowing transitions to occur over 10 year time periods.[14]

Each point on the t axis of this figure corresponds to a value for the share of a sector in GDP at time t. Standing at one particular value s_0 and looking in a straight line parallel to the $t+10$ axis, the surface of the kernel graphs a probability density over all possible values for s at time $t+10$, given the value s_0 at time t. Tracing out this probability density for all values of s at time t yields the three-dimensional graph in Figure 1. The greater the height of the ridge along the positively sloped diagonal of this figure, the greater the degree of persistence in patterns of international specialisation. An equal value of the kernel along all lines parallel to the $t+10$ access would correspond to the case of complete mobility in patterns of international specialisation.

<Figure 1 about here>

The same analysis may be undertaken for the evolution of shares of GDP predicted from countries' factor endowments. Figure 2 presents a three-

[14] These were estimated with an Epanechnikov kernel using an automatic bandwidth choice following Silverman (1986).

dimensional graph of the stochastic kernel for the predicted distribution, allowing transitions to occur over 10 year time periods.[15] The interpretation of the figure is exactly the same as above. Comparing the two stochastic kernels, it is clear that there is greater persistence over time in the distribution of predicted values for shares of GDP. The increase in persistence is greatest at high and low values for predicted shares of GDP, so that the stochastic kernel in Figure 2 exhibits 'twin peaks'. That is, observed changes in countries' factor endowments have tended to induce a polarisation of patterns of specialisation at extreme values, with increasing and decreasing specialisation in certain subsets of industries. The finding of increased persistence using continuous probability measures confirms the results of transition probability estimation.

<Figure 2 about here>

Finally, we examine the robustness of these results to introducing cross-country heterogeneity in the stochastic process determining the evolution of international specialisation over time. The conditioning exercise is undertaken in exactly the same way as before, but we now examine the evolution of the observed and predicted distributions of shares of GDP country-by-country. At the level of individual countries, there are too few cross-section units (twenty industries) to estimate stochastic kernels nonparametrically, and only transition probability matrices are estimated. Table 5 reports the estimated matrices of transition probabilities and formal indices of mobility for the observed and predicted distributions of shares of GDP in the United States. In both Table 5 and for five of the six other countries, the predicted distribution exhibits greater persistence than the observed distribution of shares of GDP as measured by all three indices of mobility. The exception is Denmark, where the predicted distribution exhibits greater persistence as measured by mobility indices M_1 and M_2, but less persistence as measured

[15] Again an Epanechnikov kernel was used with an automatic bandwidth choice following Silverman (1986).

by M_3.

<Table 5 about here>

7 Conclusions

Much of the existing empirical trade literature is concerned with the static predictions of international trade theory for cross-section patterns of international specialisation at a point in time. This contrasts with the theoretical literature on trade and growth, which emphasises that comparative advantage is dynamic and evolves endogenously over time. This paper proposes an empirical framework for analysing the dynamics of international specialisation; the framework is implemented using disaggregated data on 20 manufacturing industries in 7 OECD countries during 1970-90.

Within a single conceptual framework, we address four main sets of issues relating to the dynamics of international specialisation: changes in the overall degree of specialisation, the extent to which initial patterns of specialisation persist over time, implications for long-run patterns of specialisation, and the economic determinants of observed changes in specialisation. Each set of issues is suggested by the theoretical literature on trade and growth, and yet is a subject upon which existing empirical work has relatively little to say.

This paper focuses on the second and fourth issues above - the extent to which initial patterns of specialisation persist over time and the economic forces underlying changes in specialisation. An empirical measure of a country c's extent of specialisation in a sector j at time t is derived directly from neoclassical trade theory: the share of the sector in country c's GDP. A country's pattern of international specialisation at a point in time is fully described by the distribution of the theory-consistent measure across sectors. The dynamics of international specialisation correspond to the evolution of the entire cross-section distribution over time.

We employ a model of distribution dynamics, that is explicitly suited to an analysis of the evolution of an entire distribution. Motivated by the theoretical literature on trade and growth, the paper examines the role of changing factor endowments in explaining evolving patterns of international specialisation. The analysis begins by pooling country-industry-year observations and estimating transition probabilities using data on observed shares sectors in GDP. Evidence is found of substantial mobility in patterns of international specialisation, the extent of which we quantify using formal indices of mobility.

Neoclassical trade theory identifies a relationship between the share of a sector in GDP and countries' factor endowments. In order to evaluate the role played by changing factor endowments, we estimate this relationship using within groups and derive the values for sectoral shares of GDP predicted from countries' factor endowments. The within groups estimation reveals factor endowments to be an important determinant of patterns of international specialisation. Pooling country-industry-year observations, transition probabilities are estimated using the data on predicted values for shares of GDP.

We find greater persistence in the distribution of predicted values than in the distribution of observed values for shares of GDP. That is, observed patterns of international specialisation display more mobility than would be predicted on the basis of factor endowments. Factor endowments are a source of persistence rather than mobility in patterns of international specialisation over time. This finding is confirmed by the stochastic kernels estimated on pooled country-industry-year data and by the transition probability matrices estimated for individual countries.

8 References

Amiti, M (1997) 'Specialisation Patterns in Europe', *CEP Discussion Paper*, 363, London School of Economics

Amsden, A (1989) *Asia's Next Giant: South Korea and Late Industrialisation*, Oxford University Press, New York

Anderson, T and Goodman, L (1957) 'Statistical Inference About Markov Chains', *Annual of Mathematical Statistics*, 28, 89-110

Balassa, B (1965) 'Trade Liberalisation and Revealed Comparative Advantage', *The Manchester School of Economic and Social Studies*, 33, 99-123

Balassa, B (1979) 'The Changing Pattern of Comparative Advantage in Manufactured Goods', *Review of Economics and Statistics*, 61(2), 259-66

Barro, R and Lee, J (1993) 'International Comparisons of Educational Attainment', *NBER Working Paper*, 4349

Berman, E, Bound, J, and Machin, S (1998) 'Implications of Skill-biased Technological Change: International Evidence', *Quarterly Journal of Economics*, November, 1245-79

Bernstein, J and Weinstein, D (1998) 'Do Endowments Predict the Location of Production? Evidence from National and International Data', *NBER Working Paper*, 6815

Bowen, H (1983) 'Changes in the International Distribution of Resources and Their Impact on US Comparative Advantage', *Review of Economics and Statistics*, 65, 402-14

Bowen, H, Hollander, A, and Viaene, J (1998) *Applied International Trade Analysis*, Macmillan

Bowen, H, Leamer, E, and Sveikauskas, L (1987) 'Multicountry, Multifactor Tests of the Factor Abundance Theory', *American Economic Review*, 77, pages 791-809

Brasili, A, Epifani, P, and Helg, R (1999) 'On the Dynamics of Trade Patterns', Paper presented at Tilburg Conference on Dynamics, Growth and International Trade, University of Bocconi, mimeo

David, P (1975) *Technical Choice, Innovation, and Economic Growth*, Cambridge University Press: Cambridge UK

Davis, D and Reeve, T (1997) 'Human Capital, Unemployment, and Relative Wages in a Global Economy', Harvard University, mimeo

Davis, D, Weinstein, D, Bradford, S, and Shimpo, K (1997) 'Using International and Japanese Regional Data to Determine When the Factor Abundance Theory of Trade Works', *American Economic Review*, 87(3), 421-46

Davis, D and Weinstein, D (1998) 'An Account of Global Factor Trade', *NBER Working Paper*, 6785, November

Deardorff, A (1974) 'Factor Proportions and Comparative Advantage in the Long-run: Comment', *Journal of Political Economy*, 82(4), 829-33

Dixit, A and Norman, V (1980) *The Theory of International Trade*, Cambridge: Cambridge University Press

Eaton, J (1987) 'A Dynamic Specific-Factors Model of International Trade', *Review of Economic Studies*, 325-38

Feenstra, R and Rose, A (1997) 'Putting Things in Order: Patterns of Trade Dynamics and Growth', *NBER Working Paper*, 5975

Findlay, R (1970) 'Factor Proportions and Comparative Advantage in the Long Run', *Journal of Political Economy*, 78(1), 27-34

Findlay, R (1995) *Factor Proportions, Trade, and Growth*, MIT Press

Gabaix, X (1997) 'The Factor Content of Trade: A Rejection of the Heckscher-Ohlin-Leontief Hypothesis', Harvard University, mimeo

Geweke, J, Marshall, R, and Zarkin, G (1986) 'Mobility Indices in Continuous Time Markov Chains', *Econometrica*, 54, 1407-1423

Griffith, R, Redding, S and Van Reenen, J (1999) 'Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Manufacturing Industries', Paper presented at the NBER Summer Institute, Institute for Fiscal Studies, London, mimeo

Grossman, G and Helpman, E (1991) *Innovation and Growth in the Global Economy*, MIT Press: Cambridge MA

Hanson, H and Slaughter, M (1999) 'The Rybczynski Theorem, Factor-Price Equalisation, and Immigration: Evidence from US States', *NBER Working Paper*, 7074

Harrigan, J (1995) 'Factor Endowments and the International Location of Production: Econometric Evidence for the OECD, 1970-85', *Journal of International Economics*, 39, 123-41

Harrigan, J (1997) 'Technology, Factor Supplies, and International Specialisation: Estimating the Neoclassical Model', *American Economic Re-*

view, 87(4), pages 475-94

Harrigan, J and Zakrajsek, E (1999) 'Factor Supplies and Specialisation in the World Economy', paper presented at Tilburg conference on Growth, Dynamics and International Trade, mimeo

Helpman, E (1999) 'The Structure of Foreign Trade', *Journal of Economic Perspectives*, 13(2), 121-44

Hinloopen, J and van Marrewijk, C (1998) 'On the Empirical Distribution of Revealed Comparative Advantage 1: Shape and Time', Paper presented at the CEPR European Research Workshop in International Trade, Erasmus University, mimeo

Kim, S (1995) 'Expansion of Markets and the Geographic Distribution of Economic Activities: The Tends in U.S. Regional Manufacturing Structure, 1860-1987', *Quarterly Journal of Economics*, 110(4), 881-908

Kohli, U (1991) *Technology, Duality and Foreign Trade*, Ann Arbor: University of Michigan Press

Krugman, P (1987) 'The Narrow Moving Band, the Dutch Disease and the Competitive Consequences of Mrs Thatcher: Notes on Trade in the Presence of Scale Economies', *Journal of Development Economics*, vol 27, pages 41-55.

Lawrence, R and Slaughter, M (1993) 'International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup ?', *Brookings Papers on Economic Activity*, 2, 161-210

Leamer, E (1984) *Sources of Comparative Advantage: Theories and Evidence*, MIT Press

Leamer, E and Levinsohn, J (1995) 'International Trade Theory: The Evidence', *Handbook of International Economics*, vol 3, 1339-94

Leamer, E (1999) 'Linking the Theory with the Data: That's the Core Problem of International Economics', *Handbook of Econometrics*, forthcoming

Lucas, R (1988) 'On the Mechanics of Economic Development', *Journal of Monetary Economics*, 22, 3-22

Machin, S and Van Reenen, J (1998) 'Technology and Changes in Skill Structure: Evidence from Seven OECD Countries', *Quarterly Journal of Economics*, November, 1215-44

Maskus, K (1983) 'Evidence on Shifts in the Determinants of the Structure of US Manufacturing Foreign Trade, 1958-76, *Review of Economics and*

Statistics, 65, 415-22

Nickell, S and Bell, B (1995) 'The Collapse in Demand for the Unskilled and Unemployment Across the OECD', *Oxford Review of Economic Policy*, 11(1), pages 40-62

Nickell, S and Bell, B (1996) 'Changes in the Distribution of Wages and Unemployment in OECD Countries', *American Economic Review*, 86(2), 302-8

Porter, M (1990) *The Competitive Advantage of Nations*, Macmillan: London

Proudman, J and Redding, S (1998) 'Persistence and Mobility in International Trade', Chapter 2 in (eds) Proudman, J and Redding, S, *Openness and Growth*, Bank of England: London (formerly *CEPR Discussion Paper*, 1802)

Quah, D (1993) 'Empirical Cross-Section Dynamics in Economic Growth', *European Economic Review*, vol 37, pages 426-34

Quah, D (1996a) 'Twin Peaks: Growth and Convergence in Models of Distribution Dynamics', *Economic Journal*, 106, 1045-55

Quah, D (1996b) 'Convergence Empirics Across Economies with (some) Capital Mobility', *Journal of Economic Growth*, 1, 95-124

Quah, D (1996c) 'Aggregate and Regional Disaggregate Fluctuations', *Empirical Economics*, 21, 137-59

Quah, D (1997a) 'Empirics for Economic Growth and Distribution: Polarization, Stratification, and Convergence Clubs', *Journal of Economic Growth*, 2(1), 27-59

Quah, D (1997b) 'Regional Cohesion from Local Isolated Actions: Conditioning', *CEP Discussion Paper*, 379, London School of Economics

Redding, S (1999) 'Dynamic Comparative Advantage and the Welfare Effects of Trade', *Oxford Economic Papers*, 51, 15-39

Rivera-Batiz, L and Romer, P (1991) 'Economic Integration and Endogenous Growth', *Quarterly Journal of Economics*, 106, 531-55

Ruhashyankiko, J (1999) 'How is the World Specializing?', Centre for Economic Performance, London School of Economics, mimeo

Sachs, J and Warner, A (1995) 'Natural Resource Abundance and Economic Growth', *NBER Working Paper*, 5398

Shorrocks, A (1978) 'The Measurement of Mobility', *Econometrica*, 46, 1013-24

Silverman, B (1986) *Density Estimation for Statistics and Data Analysis*, Chapman and Hall: New York

Stern, R and Maskus, K (1981) 'Determinants of US Foreign Trade, 1958-76', *Journal of International Economics*, 11(2), 207-24

Stolpe, M (1994) 'Technology and Empirical Dynamics of Specialization in Open Economies', *Kiel Working Paper*, 637, Kiel Institute of World Economics, Germany

Summers, R and Heston, A (1991) 'The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-88', *Quarterly Journal of Economics*, 106(2), 321-68

Trefler, D (1995) 'The Case of the Missing Trade and Other Mysteries', *American Economic Review*, 85(5), pages 1029-46

Woodland, A (1982) *International Trade and Resource Allocation*, North Holland: Amsterdam

Appendix A: Conditioning Regressions

Table A1: Endowments Regressions, Panel 1

Dependent Var.	sgdp
Obs	2940
Years	70-90

	Coef.	**Std. Err.**	P>|t|
1. Food			
nprod	-1.3207	0.2053	0.000
prod	2.5608	0.3293	0.000
dkap	-0.6609	0.1710	0.000
okap	0.3779	0.1305	0.004
arable	-0.6620	0.0753	0.000
2. Textiles			
nprod	1.7286	0.2174	0.000
prod	-2.8525	0.3486	0.000
dkap	0.7570	0.1805	0.000
okap	-0.5740	0.1385	0.000
arable	0.6616	0.0799	0.000
3. Wood			
nprod	0.9755	0.2307	0.000
prod	-1.9812	0.3670	0.000
dkap	0.4473	0.1901	0.019
okap	0.1559	0.1472	0.290
arable	0.2551	0.0838	0.002
4. Paper			
nprod	3.0888	0.5082	0.000
prod	-4.3688	0.8215	0.000
dkap	1.3112	0.4074	0.001
okap	-1.4233	0.3291	0.000
arable	0.8688	0.1807	0.000
5. Chemicals			
nprod	0.0386	0.3522	0.913
prod	0.1860	0.5679	0.743
dkap	-1.0352	0.2892	0.000
okap	1.1926	0.2261	0.000
arable	-0.3099	0.1282	0.016

Table A1: Endowments Regressions, Panel 2

	Coef.	Std. Err.	P>|t|
6. Drugs			
nprod	0.7309	0.3570	0.041
prod	-2.7559	0.5772	0.000
dkap	1.7607	0.2986	0.000
okap	-0.3364	0.2236	0.133
arable	0.2806	0.1304	0.032
7. Petroleum			
nprod	1.3103	0.3474	0.000
prod	-2.7335	0.5359	0.000
dkap	1.0721	0.2679	0.000
okap	-0.5056	0.2161	0.019
arable	0.5824	0.1216	0.000
8. Rubber			
nprod	0.9698	0.4229	0.022
prod	-0.2771	0.7259	0.703
dkap	-1.2764	0.3912	0.001
okap	0.7325	0.2811	0.009
arable	-0.0148	0.1567	0.925
9. Minerals			
nprod	0.9631	0.2267	0.000
prod	-1.4701	0.3665	0.000
dkap	-0.2176	0.1906	0.254
okap	0.1704	0.1439	0.236
arable	0.4070	0.0827	0.000
10. Ferrous			
nprod	1.1522	0.2372	0.000
prod	-2.2021	0.3761	0.000
dkap	0.4847	0.1928	0.012
okap	-0.1520	0.1510	0.314
arable	0.4118	0.0870	0.000
11. Non-ferrous			
nprod	1.3168	0.2202	0.000
prod	-2.5794	0.3503	0.000
dkap	0.6950	0.1804	0.000
okap	-0.2104	0.1391	0.131
arable	0.5703	0.0801	0.000
12. Metals			
nprod	1.6561	0.2320	0.000
prod	-2.9859	0.3679	0.000
dkap	0.5913	0.1871	0.002
okap	0.0490	0.1468	0.739
arable	0.4832	0.0845	0.000

Table A1: Endowments Regressions, Panel 3

	Coef.	Std. Err.	P>|t|
13. Office Equip.			
nprod	-4.4594	0.9273	0.000
prod	3.6488	1.3554	0.007
dkap	-1.2040	0.6513	0.065
okap	2.9460	0.5589	0.000
arable	-1.0059	0.3010	0.001
14. Non-electrical			
nprod	0.5779	0.2585	0.025
prod	-1.7350	0.3943	0.000
dkap	0.5648	0.2003	0.005
okap	-0.0690	0.1602	0.667
arable	0.4364	0.0904	0.000
15. Radio, TV			
nprod	1.8549	0.2244	0.000
prod	-3.7667	0.3622	0.000
dkap	1.4708	0.1891	0.000
okap	-0.6868	0.1451	0.000
arable	0.9270	0.0834	0.000
16. Electrical			
nprod	1.4504	0.2631	0.000
prod	-2.1072	0.4038	0.000
dkap	0.1855	0.1990	0.351
okap	0.1190	0.1632	0.466
arable	0.2292	0.0922	0.013
17. Shipbuilding			
nprod	1.4076	0.2112	0.000
prod	-2.2122	0.3375	0.000
dkap	0.4164	0.1750	0.017
okap	-0.3026	0.1343	0.024
arable	0.4806	0.0774	0.000
18. Motor Vehicles			
nprod	0.9563	0.2505	0.000
prod	-2.3653	0.4181	0.000
dkap	0.7280	0.2309	0.002
okap	-0.1421	0.1671	0.395
arable	0.4389	0.0990	0.000
19. Professional			
nprod	-0.3999	0.3676	0.277
prod	0.2413	0.5148	0.639
dkap	-0.2481	0.2461	0.313
okap	0.4472	0.2246	0.047
arable	-0.0992	0.1215	0.414

Table A1: Endowments Regressions, Panel 4

	Coef.	Std. Err.	P>|t|
20. Other			
nprod	-1.0882	0.4170	0.009
prod	-0.2563	0.6472	0.692
dkap	-0.0966	0.3267	0.768
okap	1.2215	0.2602	0.000
arable	0.0076	0.1430	0.957

Industry Fixed Effects	yes (20)
Year-Industry Dummies	yes (400, 71-90)

Diagnostics	
F(519, 2420)	127.13
Prob > F	0.0000
R-squared	0.9118
Root MSE	0.2929

Standard errors are Huber-White heteroscedasticity robust

Dependent variable: share of sector in GDP (%). Independent variables: log number of non-production workers (thousands), log number of production workers (thousands), log stock of durable capital (thousands of 1985 US dollars), log stock of other capital (thousands of 1985 US dollars), and log arable land (thousands of hectares)

Appendix B: Occupation and Education-based Classifications of Skills

This paper follows a large number of other authors in using data on non-production and production workers to measure skills (see for example Berman, Bound, and Machin (1998) and Lawrence and Slaughter (1993)). The main alternative is to use data on educational attainment (see for example Nickell and Bell (1995), (1996)). These are not currently available on an annual basis for all countries and years during the sample period (in Barro and Lee (1993) information is presented every five years for the period 1960-85), but annual data on the proportion of workers with the equivalent of a college degree or higher is available for total manufacturing in the United Kingdom and United States during 1977-90.[16] Table B1 reports time series correlations between the proportion of workers with the equivalent of a college degree or higher and the proportion of non-production workers. In both the United Kingdom and United States, we find a high degree of correlation between the two measures of skills during 1977-90.

Table B1: Time series correlations between occupation-based and education-based classifications of skills in the United Kingdom and United States, 1977-90

Country	1977-90	1977-90
United Kingdom	0.9229	-
United States	-	0.9273

Data sources: United Nations General Industrial Statistics Database (UNISD), UK Labour Force Survey, and US Current Population Survey. See Appendix C and Machin and Van Reenen (1998) for further details.

[16]These data were supplied by John Van Reenen and are aggregated from the individual level: from the Labour Force Survey in the United Kingdom and the Current Population Survey in the United States. For further details concerning the data used, see Machin and Van Reenen (1998).

Appendix C: Data Appendix

OECD Structural Analysis Industrial (STAN) database: data on current price value-added (US dollars) for the twenty manufacturing sectors listed in Table B1 (International Standard Industrial Classification (ISIC)), 1970-90.

OECD International Sectoral Database (ISDB): data on constant price value-added (1985 US dollars) and capital stock (1985 US dollars) for the twelve manufacturing sectors listed in Table 3 (International Standard Industrial Classification (ISIC)), 1970-90. See Griffith, Redding, and Van Reenen (1999) for further discussion of the data.

Penn World Tables 5.6: data on current price GDP per capita (US dollars), population (thousands), non-residential capital stock (1985 US dollars), and Producer durables (% of non-residential capital stock, 1985 US dollars), 1970-90. See Summers and Heston (1991) for further discussion of the data. These may be downloaded from http://arcadia.chass.utoronto.ca/pwt/.

United Nations General Industrial Statistics Database (UNISD): data on the proportion of non-production and production workers in total manufacturing, 1970-90. For the United States, data on the proportion of non-production and production workers are also available for the twelve manufacturing sectors listed in Table 3 (International Standard Industrial Classification (ISIC)). See Berman, Bound and Machin (1998) and Machin and Van Reenen (1998) for further discussion of the data.

FAO Arable Land Data: data on hectares of arable land (thousands) from the United Nations Food and Agricultural Organisation (FAOSTAT), 1970-90. These may be downloaded from http://www.fao.org.

Country Converage: Canada, Denmark, Finland, Japan, Sweden, United Kingdom, and United States

Table C1
Industrial Classification

Industry	ISIC Classification
1. Food, Drink and Tobacco	3100
2. Textiles, Footwear and Leather	3200
3. Wood, Cork and Furniture	3300
4. Paper, Print and Publishing	3400
5. Chemicals excl. Drugs	3512
6. Durgs and Medicines	3522
7. Petroleum Refineries and Products	3534
8. Rubber and Plastic Products	3556
9. Non-metallic Minerals	3600
10. Ferrous Metals	3710
11. Non-ferrous Metals	3720
12. Metal Products	3810
13. Office and Computing Equipment	3825
14. Non-electrical Machinery	3829
15. Radio, TV and Communication	3832
16. Other Electrical Machinery	3839
17. Shipbuilding & Repairing	3841
18. Motor Vehicles	3843
19. Professional Goods	3850
20. Other Manufacturing	3900

Table 1: Share of manufacturing in GDP and share of industries in total manufacturing in 1970 and 1990 (%), Panel A

Industry	Year	Can	Den	Fin	Jap	Swe	UK	USA
Food	**1970**	14.86	20.96	13.26	10.57	8.13	13.32	12.33
	1990	14.55	20.54	11.76	10.16	10.18	13.36	10.72
Textiles	**1970**	8.35	8.89	9.94	7.26	6.17	10.32	7.93
	1990	5.43	4.64	3.87	4.65	2.16	6.24	4.99
Wood	**1970**	5.78	5.96	9.94	3.55	8.12	2.63	4.34
	1990	6.47	5.60	8.81	2.71	7.66	3.05	4.58
Paper	**1970**	13.98	11.40	22.46	5.84	14.91	8.45	9.12
	1990	15.81	10.88	20.89	7.39	15.20	11.07	11.56
Chemicals	**1970**	4.99	4.82	5.08	7.85	4.40	8.07	6.93
	1990	6.31	5.20	5.87	5.60	4.73	8.28	8.62
Drugs	**1970**	1.02	1.08	0.55	2.08	0.81	1.52	1.37
	1990	1.97	3.68	0.94	2.29	2.12	3.14	2.82
Petroleum	**1970**	1.34	1.26	2.13	1.22	1.18	1.14	1.47
	1990	1.43	1.19	2.60	0.59	2.50	2.03	2.01
Rubber	**1970**	2.59	2.76	2.29	3.03	2.71	2.90	2.27
	1990	3.23	3.46	1.83	3.92	2.43	4.42	3.74
Minerals	**1970**	3.54	7.45	4.22	4.21	3.99	3.51	3.23
	1990	3.19	4.43	4.86	3.61	3.18	3.72	2.41
Ferrous	**1970**	5.17	1.27	3.19	9.05	7.26	6.31	5.30
	1990	2.98	0.96	3.07	5.84	3.20	3.18	2.67
Non-ferrous	**1970**	3.80	0.54	1.27	2.26	2.19	1.68	2.06
	1990	3.07	0.32	1.31	1.97	1.45	1.09	1.47
Metals	**1970**	6.70	7.22	4.51	5.99	9.69	6.57	7.31
	1990	5.54	8.72	6.71	5.90	10.39	5.84	6.73
Office Equip.	**1970**	1.53	0.49	0.13	1.18	1.23	0.79	1.30
	1990	0.96	0.73	1.49	3.26	0.58	2.22	1.87
Non-electrical	**1970**	6.76	10.70	10.03	9.52	11.63	10.38	10.28
	1990	6.47	14.08	11.30	9.86	13.11	9.48	9.26
Radio, TV	**1970**	2.63	1.93	0.84	5.57	2.89	3.68	2.67
	1990	3.71	2.41	3.34	9.05	3.52	4.41	5.56
Electrical	**1970**	3.57	4.78	3.37	5.28	3.97	4.05	4.71
	1990	2.92	3.23	3.65	6.94	3.24	4.28	3.64
Shipbuilding	**1970**	0.65	3.38	3.38	2.32	1.94	1.78	0.78
	1990	0.52	3.25	2.40	0.60	0.95	1.00	0.67
Motor Vehicles	**1970**	7.27	0.97	1.06	7.83	4.60	5.91	6.52
	1990	9.34	1.18	1.94	8.64	8.19	5.74	4.47
Professional	**1970**	1.85	1.14	0.44	1.66	0.87	1.87	3.82
	1990	1.66	2.66	1.31	1.82	2.44	1.42	5.06
Other	**1970**	1.00	1.58	0.94	3.06	0.61	1.08	1.66
	1990	0.89	2.55	0.83	4.67	0.68	1.09	1.96
Total	**1970**	19.31	17.39	22.43	36.71	22.73	29.46	24.67
	1990	14.71	15.63	19.38	28.51	18.58	20.45	18.87

Notes: See Appendix C for a list of industry names in full and International Standard Industrial Classification (ISIC) Codes. Data sources: OECD STAN database and Penn World Tables 5.6 (see Appendix C).

Table 2: Relative factor abundance (%)

Country	Year	GDP	Non-prod	Prod	Durable Capital	Other Capital	Arable
Can	**1970**	4.83	5.06	5.37	2.98	7.27	17.25
	1990	5.84	3.86	6.56	4.12	7.68	18.31
Den	**1970**	1.14	1.00	1.32	1.23	1.44	1.05
	1990	0.94	0.93	1.16	0.96	1.16	1.02
Fin	**1970**	0.86	0.75	1.31	1.28	1.53	1.06
	1990	0.90	0.87	1.15	1.05	1.49	1.02
Jap	**1970**	18.15	35.55	21.65	17.61	19.24	1.94
	1990	23.10	37.63	19.13	28.90	34.82	1.65
Swe	**1970**	2.07	1.78	2.08	1.98	2.50	1.21
	1990	1.64	1.50	1.97	2.33	1.88	1.14
UK	**1970**	10.87	11.85	14.60	14.97	6.60	2.82
	1990	9.59	10.77	12.79	10.17	5.37	2.64
US	**1970**	62.07	44.01	53.67	59.95	61.42	74.67
	1990	57.99	44.44	57.25	52.47	47.60	74.23

Note: See main text for definition of relative factor abundance. Data Sources: Penn World Tables 5.6, United Nations General Industrial Statistics Database (UNISD), and United Nations FAO. See Appendix C for further details.

Table 3: Factor Intensities, United States
Sample means, 1970-90

Industry	ISIC	Non-prod. Intensity	Production Intensity	Capital Intensity
Food, Beveridges	31	6.62	15.81	1.68
Textiles, Apparel	32	7.66	48.98	1.64
Wood Products	33	5.91	31.18	1.39
Paper, Printing	34	9.03	15.71	1.53
Chemicals	35	6.21	13.07	2.83
Minerals	36	5.92	21.41	2.77
Primary Metals	37	4.84	17.70	3.75
Metal Products	381	6.85	21.38	1.59
Non-elec. Machinery	382	8.20	16.32	1.63
Electrical Machinery	383	9.63	18.63	1.73
Shipbuilding	384	6.13	14.65	1.69
Professional Goods	385	12.10	18.11	1.16
Mean		7.42	21.08	1.95
Coefficient of Var.		0.30	0.50	0.42

Note: Non-production and production intensities are defined as numbers of workers per million dollars of real value-added (1985 US dollars). Physical capital intensity is defined as number of dollars of physical capital per dollar of value-added (1985 US dollars). Data Sources: OECD International Sectoral Database (ISDB) and United Nations General Industrial Statistics Database (UNISD). See Appendix C and Griffith, Redding and Van Reenen (1999) for further details.

Table 4: Transition probabilities, pooled sample 5-year transitions, 1971-85

sgdp	Upper Endpoint				
Number	0.330	0.620	1.03	1.79	∞
(422)	0.82	0.18	0.00	0.00	0.00
(394)	0.18	0.72	0.09	0.00	0.00
(414)	0.01	0.19	0.73	0.07	0.00
(437)	0.00	0.02	0.22	0.70	0.06
(433)	0.00	0.00	0.00	0.18	0.82
Ergodic	0.386	0.369	0.175	0.051	0.021

Predicted	Upper Endpoint				
Number	0.390	0.725	1.120	1.950	∞
(415)	0.88	0.12	0.00	0.00	0.00
(425)	0.16	0.70	0.14	0.00	0.00
(403)	0.01	0.13	0.80	0.06	0.00
(425)	0.00	0.00	0.16	0.76	0.08
(432)	0.00	0.00	0.00	0.14	0.86
Ergodic	0.340	0.248	0.257	0.098	0.057

Mobility Indices	sgdp	pred.
$M_1 = \frac{n - tr[Z]}{n-1}$	0.30	0.25
$M_2 = \frac{n - \sum_x \lvert\xi_x\rvert}{n-1}$	0.30	0.25
$M_3 = 1 - \lvert\det(Z)\rvert$	0.79	0.71

Table 5
Transition probabilities, United States
5-year transitions, 1971-85

sgdp	Upper Endpoint				
Number	0.41	0.69	1.05	1.66	∞
(61)	0.79	0.21	0.00	0.00	0.00
(59)	0.22	0.61	0.17	0.00	0.00
(53)	0.02	0.17	0.74	0.08	0.00
(63)	0.00	0.06	0.25	0.67	0.02
(64)	0.00	0.00	0.00	0.20	0.80
Ergodic	0.351	0.317	0.264	0.063	0.005

Predicted	Upper Endpoint				
Number	0.440	0.775	1.190	1.750	∞
(61)	0.92	0.08	0.00	0.00	0.00
(48)	0.10	0.85	0.04	0.00	0.00
(66)	0.00	0.26	0.59	0.15	0.00
(60)	0.00	0.00	0.38	0.57	0.05
(65)	0.00	0.00	0.00	0.17	0.83
Ergodic	0.505	0.398	0.064	0.025	0.008

Mobility Indices	sgdp	pred.
$M_1 = \frac{n-tr[Z]}{n-1}$	0.35	0.31
$M_2 = \frac{n-\sum_x \lvert\xi_x\rvert}{n-1}$	0.35	0.31
$M_3 = 1 - \lvert\det(Z)\rvert$	0.85	0.83

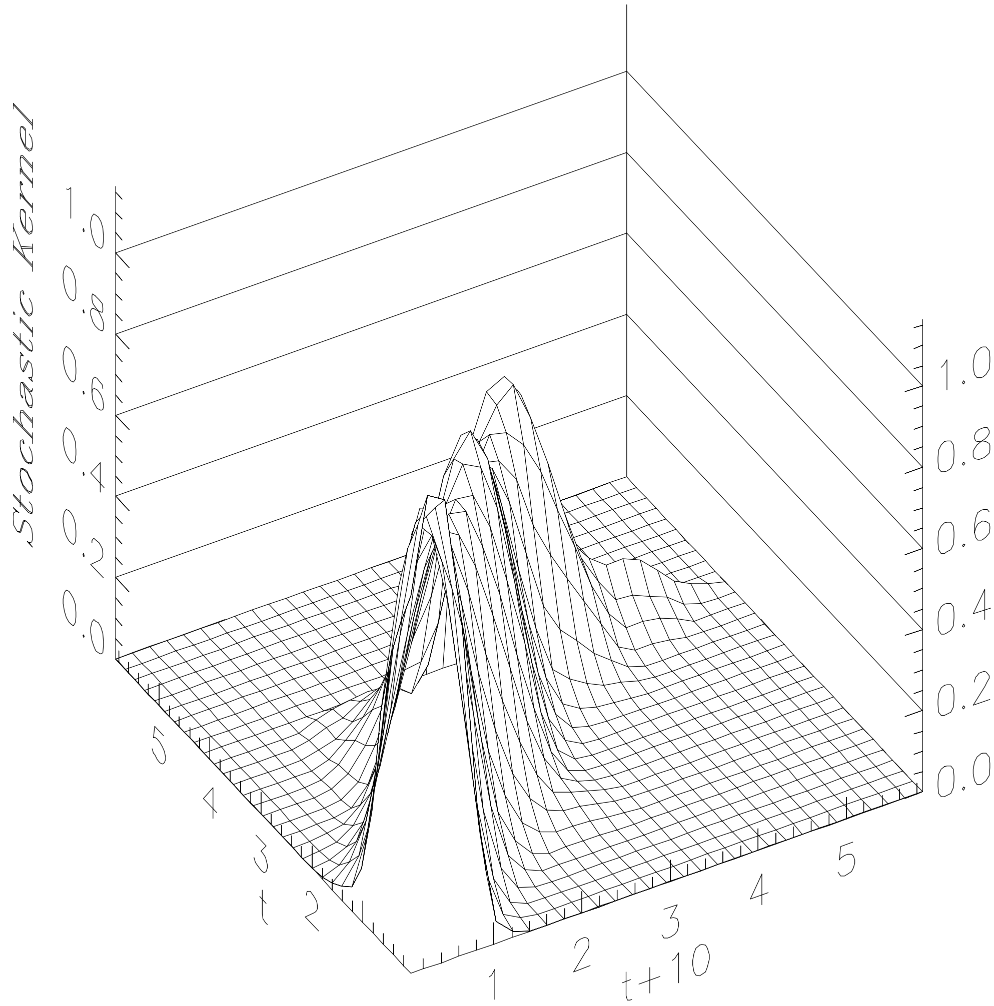

Figure1: Stochastic kernel for sgdp, 3d plot, 10 year transitions

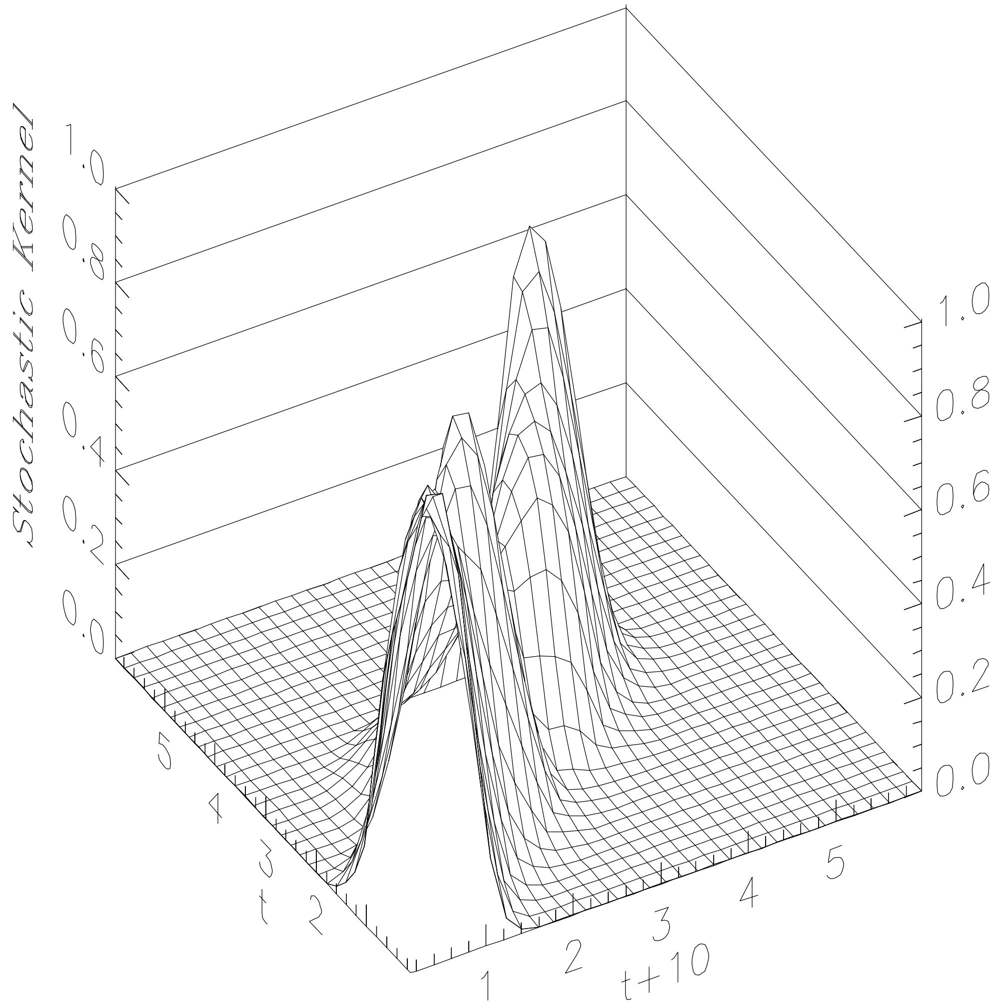

Figure 3: Stochastic kernel for predicted, 3d plot, 10 year transitions