Persistence and Mobility in International Trade

James Proudman and Stephen Redding*

* Bank of England, Threadneedle Street, London, EC2R 8AH

The views expressed are those of the authors and do not necessarily reflect those of the Bank of England. We would like to thank Gavin Cameron, Nigel Jenkinson, Danny Quah, Andrew Scott, Jon Temple, Peter Westaway, an anonymous referee, and participants in seminars at the Bank of England and the Royal Economic Society Conference 1997 for their helpful comments. We are grateful to Jon Temple for first suggesting the use of formal indices of mobility. We are also grateful to Mark Thirlwell who calculated the original measure of RCA used in this paper, to Colin Webb for help with the data and to Kee Law for excellent research assistance. We would like to thank (without implicating) Danny Quah for making the TSRF econometrics package available to us. Any errors are the authors' responsibility.

Issued by the Bank of England, Threadneedle Street, London, EC2R 8AH, to which requests for individual copies should be addressed: envelopes should be marked for the attention of the Publications Group. (Telephone: 0171 601 4030).

ISSN 1368-5562

Contents

Abstract

The theoretical literature on endogenous growth and international trade suggests that comparative advantage is endogenous. *Sector-specific learning by doing* and *technology transfer* respectively provide reasons why initial patterns of international specialisation may *persist* or exhibit *mobility* over time. This paper evaluates the extent of persistence or mobility in trade in manufactured goods in the United Kingdom and Germany for the period 1970-93. A measure of the extent of specialisation is presented and its evolution over time modelled as a sequence of cross-section distributions. Evidence of considerable mobility is found, with the degree of mobility in the United Kingdom exceeding that in Germany.

J.E.L. CLASSIFICATION: C10,F10,030

KEYWORDS: Distribution Dynamics, International Trade, Learning by Doing, Markov Chains, Revealed Comparative Advantage, Technological Change

1 Introduction

International trade dynamics have received relatively little attention in the existing empirical literature. It seems likely that this reflects the fact that, until recently, most international trade models were framed in a static world. This paper undertakes an empirical analysis of the dynamics of patterns of international specialisation in the United Kingdom and Germany. A disaggregated data set is employed that provides information by sector on manufacturing exports to the 23 OECD economies and 15 trade partners for the period 1970 to 1993. Although the focus of the analysis is very much on the United Kingdom, Germany is considered as a comparator country at a similar level of industrial development.

A measure of the extent of specialisation in an individual manufacturing sector is presented based on Balassa (1965)'s concept of Revealed Comparative Advantage (RCA). An economy's pattern of international specialisation at any one point in time may be characterised in terms of the cross-section distribution of RCA over manufacturing sectors, while international trade dynamics correspond to the evolution of this distribution over time. A number of interesting questions relating to the pattern of specialisation *at a point in time* may be addressed: for example, the degree to which each economy specialises in a limited range of industries and the identities of these industries. However, this framework also facilitates an analysis of a more interesting set of issues pertaining to international trade *dynamics*. First, we examine how the *degree* of international specialisation has changed over time (how the *external shape* of the distribution has changed over time). Second, we consider the extent to which initial patterns of international specialisation either *persist* or exhibit *mobility* over time (a question of *intra-distribution dynamics*).

The objective of this paper is to present a framework within which it is possible to address these kinds of questions, while at the same time imposing as little theoretical structure on the data as possible. International specialisation is measured using actual trade data and its evolution over time characterised using techniques for modelling distribution dynamics, that have typically been employed in the economics literature to model income dynamics (see in particular Quah (1993), (1996a) and (1996c)). In this paper, we wish to *characterise* patterns of international specialisation and their evolution over time, without making any assumptions as to what is determining these phenomena. Nonetheless, the empirical analysis of trade dynamics is very much motivated by the recent theoretical literature on endogenous growth and international trade. This literature emphasises that comparative advantage is both endogenously *determined* by the history of technological change and endogenously *determines* current rates of innovation (see for example Grossman and Helpman (1991) and Redding (1996)). Furthermore, the literature identifies a number of forces that militate towards either *persistence* or *mobility* in patterns of international trade.

Hence, Section 2 begins with a simple theoretical model of international trade dynamics. The past history of technological change interacts with the current pattern of international specialisation to determine endogenously rates of productivity growth and the evolution of international specialisation over time. *Sector-specific learning by doing* engenders *persistence*, while *technology transfer* is a force for *mobility.* In addition, variation across sectors in an *exogenous* source of productivity growth may militate towards either *persistence* or *mobility*, depending upon the correlation between the exogenous sources of productivity growth and the initial pattern of international specialisation.

Section 3 introduces a measure of the extent of international specialisation based on Balassa (1965)'s concept of Revealed Comparative Advantage (RCA). The pattern of international specialisation at any one point in time is characterised in terms of a distribution of RCA across manufacturing sectors. Section 4 models the dynamics of patterns of international specialisation formally in terms of the evolution of this distribution over time. Indices of the degree of mobility in patterns of RCA in the United Kingdom and Germany are presented, and the extent of mobility in the United Kingdom and Germany compared. Finally, Section 5 concludes.

2 Theoretical framework

In order to motivate the empirical analysis that follows, this section presents a simple theoretical model of international trade dynamics. Static equilibrium is determined exactly as in the standard Ricardian model with a continuum of goods (Dornbusch *et al.* (1977)). There are two economies (home and foreign) and A_{ij} denotes the productivity of skilled labour in sector j of economy $i \in \{H, F\}$. An individual good $j \in [0, n]$ will be produced in home (H) if and only if the unit cost of producing that good in home is below or equal to that in foreign (F),

$$\frac{w_H(t)}{w_F(t)} \leq \underbrace{\frac{A_{Hj}(t)}{A_{Fj}(t)}}_{B_j(t)} \tag{1}$$

where w_H and w_F are the home and foreign wage rates respectively.

Goods are indexed such that higher values of j correspond to lower levels of home productivity relative to foreign (B_j), and the right-hand side of **(1)** is illustrated diagrammatically by the downward sloping curve in Figure 1. All goods $j \leq \tilde{j}$ are produced in home and all goods $j > \tilde{j}$ are produced in foreign, where $\tilde{j}$ denotes the limit good such that home's relative wage is exactly equal to home productivity relative to foreign's.

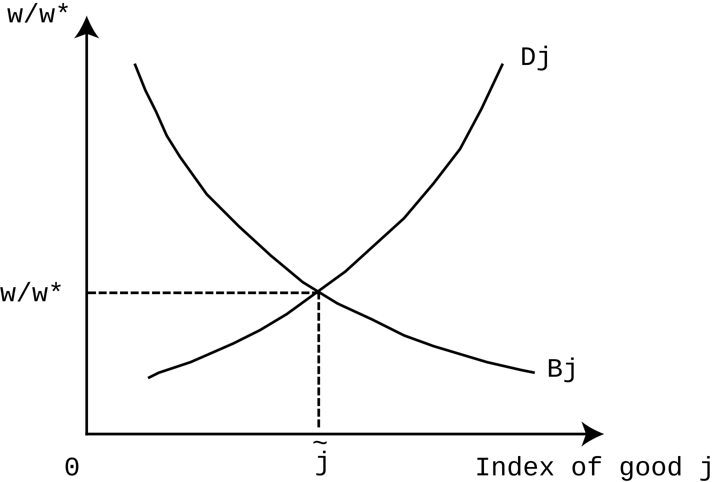
In static equilibrium, we require home's relative wage w_H/w_F to be consistent with the requirement that home income equals world expenditure on home goods (or alternatively that trade is balanced). Under the assumption that instantaneous utility is a symmetric, Cobb-Douglas function of the consumption of each good j (with the elasticity of instantaneous utility with respect to the consumption of each good equal to β), this condition may be expressed as,

$$\frac{w_H}{w_F} = \underbrace{\frac{\tilde{j}.\beta}{1-\tilde{j}.\beta}.\frac{\bar{L}^*}{\bar{L}}}_{D(\tilde{j})} \tag{2}$$

where $\bar{L}$ and $\bar{L}^*$ are the home and foreign supplies of skilled labour respectively, and the right-hand side of **(2)** is illustrated diagrammatically by the upward sloping curve in Figure 1. Static equilibrium is defined by the intersection of the two curves, where both **(1)** and **(2)** are satisfied.

Figure 1

Static equilibrium and international specialis



This standard Ricardian model is then augmented with a specification of the dynamics of productivity A_{ij} in each sector j of economy i. A wide range of empirical evidence suggests that both learning by doing and technology transfer are important determinants of rates of productivity growth (see for example Lucas (1993) and Coe and Helpman (1995)). This paper extends the specification of technological catch-up in Bernard and Jones (1996), to incorporate learning by doing in each sector following Krugman (1987).[1] Specifically, we assume that $A_{ij}(t)$ evolves according to the following difference equation,

$$\ln\left(\frac{A_{ij}(t)}{A_{ij}(t-1)}\right) = \gamma_{ij} + \psi . L_{ij} + \lambda \ln\left(\frac{A_{Xj}(t-1)}{A_{ij}(t-1)}\right), \qquad \psi, \lambda \geq 0, \quad \forall i, j \tag{3}$$

where A_{Xj} denotes productivity in sector j in whichever of the two economies $i \in \{H, F\}$ is the world's technological leader, γ_{ij} is a sector and country-specific constant reflecting the exogenous determinants of the rate of technological change, ψ parameterises the rate of learning by doing and λ parameterises the rate of technological catch-up.

Technological change is modelled as a pure externality of current production and is therefore consistent with the assumption of perfect competition in the Ricardian model. Learning by doing is *specific* to a sector and economy, but spillovers of technological knowledge occur across economies at a rate parameterised by λ. Suppose that foreign is the world technological leader, then, from **(3)**, the evolution of home productivity in sector j relative to foreign's may be expressed as,

$$\begin{aligned} \triangle \ln\left(\tfrac{A_{Hj}(t)}{A_{Xj}(t)}\right) &= (\gamma_{Hj} - \gamma_{Xj}) + \psi\left(L_{Hj}(t) - L_{Xj}(t)\right) \\ &\qquad - \lambda . \ln\left(\tfrac{A_{Hj}(t-1)}{A_{Xj}(t-1)}\right) \end{aligned} \tag{4}$$

where, since foreign is the world technological leader, $A_{Hj}/A_{Xj} \leq 1$.

The dynamics of international trade patterns are fully characterised by the static equilibrium conditions **(1)** and **(2)**, and the specification

[1] See also Bernard and Jones (1994). In both papers, Bernard and Jones are concerned with the evolution of relative levels of total factor productivity across industries and countries, rather than the dynamics of international trade that are the remit of the present paper.

of productivity growth in equations **(3)** and **(4)**. Learning by doing is a force towards *persistence* in initial patterns of comparative advantage and international specialisation, while technology transfer militates towards *mobility*. Variation in the exogenous rates of productivity growth across sectors may engender persistence or mobility. Whether actual patterns of international trade are characterised by persistence or mobility will depend upon the net effect of these three forces.

To make this clearer, suppose for example that there is a common rate of exogenous technological change across all sectors and economies ($\gamma_{ij} = \gamma_{Fj} = \gamma$ for all i, j) and no international knowledge spillovers ($\lambda = 0$). Static equilibrium at time t implies that home will specialise completely in the production of the range of goods $j \in [0, \tilde{j}]$ and foreign in goods $j \in (\tilde{j}, n]$. That is, in home, $L_j(t) > 0$ for $j \in [0, \tilde{j}]$ and $L_j(t) = 0$ for $j \in (\tilde{j}, n]$; while in foreign $L_j(t) = 0$ for $j \in [0, \tilde{j}]$ and $L_j(t) > 0$ for $j \in (\tilde{j}, n]$. Hence, from **(3)** and the parameter restrictions imposed above, home and foreign will only enjoy productivity growth in the sectors in which they initially specialise. In this case, initial patterns of international specialisation *persist* and will become increasingly *locked in* over time as in Krugman (1987).

Technology transfer ($\lambda > 0$) and variations in exogenous rates of productivity growth γ_{ij} across sectors/economies both provide reasons why an economy might enjoy more rapid productivity growth than its trade partner in sectors in which it does not initially specialise. In this case, in contrast to Krugman (1987), initial patterns of comparative advantage and international specialisation may be *reversed* over time, so that patterns of international specialisation exhibit *mobility* instead.

3 Revealed Comparative Advantage

With the theoretical analysis of the previous section as motivation, the remainder of this paper turns to an empirical analysis of international trade dynamics. In this empirical analysis, we seek to characterise the extent of *mobility* or *persistence* in patterns of international specialisation. This characterisation may be achieved by directly examining data on trade flows: we employ an index of international specialisation that follows Balassa (1965) and that is termed *Revealed Comparative Advantage* (denoted by RCA^T). An economy i's RCA^T in sector j is given by the ratio of its share of exports in sector j to its share of total exports in all sectors,

$$RCA_{ij}^{T} = \frac{Z_{ij} / \sum_i Z_{ij}}{\sum_j Z_{ij} / \sum_i \sum_j Z_{ij}} \tag{5}$$

where Z_{ij} denotes the value of economy i's exports in sector j. A value of RCA_{ij}^{T} above unity indicates an industry in which country i's share of exports exceeds its share of total exports: that is, an industry in which country i *specialises.*

Revealed Comparative Advantage yields information about the pattern of international specialisation insofar as it evaluates an economy's export share in an individual sector relative to some benchmark (here the economy's share of total exports, reflected in the T (for 'total') superscript in equation **(5)**). However, at the same time, it suffers from the disadvantage that the mean value of RCA^T is not necessarily equal to one. Specifically, the numerator in equation **(5)** is unweighted by the proportion of total exports accounted for by a given sector (while the denominator is effectively a weighted average of export shares in all manufacturing sectors). Hence, if an economy's pattern of trade is characterised by high export shares in a few sectors each of which accounts for a small share of total world exports (as is generally true for small economies), then the economy will be characterised by high values for the numerator and low values for the denominator in equation **(5)** and a mean RCA^T of above one.(2) Furthermore, mean values of RCA^T may change over time so that, as measured by RCA^T, an economy exhibits changes in its average extent of specialisation.

However, in any empirical analysis of the change in patterns of international specialisation across individual sectors, one wishes to abstract from variation in an economy's average extent of specialisation. Therefore, this paper proposes an *alternative* measure of Revealed Comparative Advantage, RCA^M, in which an economy's export share in a given sector is evaluated relative to a different benchmark, namely its *average* export share in all manufacturing sectors. In sector j of

(2) A simple example will make this clear: suppose that there are two economies (England and France) and two goods (beer and wine). The total value of England's exports is £500 (£400 Beer and £100 Wine) and the total value of France's is £10,100 (£100 Beer and £10,000 Wine). It is straighforward to show that England's mean RCA is considerably above one (it is in fact 8.59) and France's considerably below one (it is in fact 0.63).

economy i, RCA_{ij}^M is thus,[3]

$$RCA_{ij}^M = \frac{Z_{ij} / \sum_i Z_{ij}}{\frac{1}{N} \sum_j \left(Z_{ij} / \sum_i Z_{ij} \right)} \qquad \mathbf{(6)}$$

where the superscript M reflects the normalisation by mean export share. By construction, the mean value of RCA^M is constant and equal to one.[4] Throughout the remainder of this paper, Revealed Comparative Advantage is measured by RCA^M, as defined in equation **(6)**, and, to save notation, we omit the superscript.

RCA constitutes an index of international specialisation in so far as an economy's export share in an individual sector is evaluated relative to the benchmark of the average share in all manufacturing sectors. An economy's pattern of international specialisation may be represented in terms of a distribution of RCA across sectors, with values of RCA above one denoting sectors in which an economy specialises. Analysing this distribution *at any one point in time* yields information about the current pattern of specialisation: in which sectors an economy specialises in and to what extent. Examining the evolution of the entire cross-section distribution *over time* provides information concerning the dynamics of patterns of international specialisation. On the one hand, issues such as whether initial patterns of specialisation *persist* or exhibit *mobility* over time correspond to questions of *intra-distribution dynamics*: whether a sector for example moves from the lower to the upper quartile of the RCA distribution. On the other hand, changes in the overall degree of international specialisation relate to the evolution of the *external shape* of the distribution over time: whether the distribution of RCA polarises into two extremes or tends to remain roughly uniformly distributed across industries.

The data source for the empirical analysis is the OECD's Bilateral Trade Database (BTD), which provides consistent information on

[3] It is straightforward to show that $RCA_{ij}^M = RCA_{ij}^T / \frac{1}{N} \sum_j RCA_{ij}^T$, so that an alternative interpretation of the present analysis is that, at each point in time, we normalise Balassa's measure of Revealed Comparative Advantage RCA^T by its cross-sectional mean in order to abstract from the changes in the average extent of specialisation that this measure is subject to.

[4] Note that, in the definition of RCA^T in equation **(5)**, the normalisation by an economy's share of total exports is in fact a normalisation by a weighted sum of export shares in all manufacturing sectors (where the weights are the shares of each sector in total exports). The difference between RCA^M and RCA^T is therefore the normalisation by an arithmetic mean rather than a weighted sum.

exports to the OECD and 15 trade partners for 22 manufacturing industries for the period 1970 to 1993.[5] We begin by characterising the distribution of RCA at any one point in time in each of the two economies. Table A presents measures of RCA for the United Kingdom and Germany in each of the 22 manufacturing industries in the sample for the period 1970 to 1993.

Each economy's export share in a given sector is evaluated relative to its own average export share in all manufacturing industries.[6] Since we are primarily concerned with long-run changes in the pattern of international specialisation and wish to abstract from short-run fluctuations, the data are presented in the form of five-year averages. The United Kingdom's and Germany's patterns of RCA show some similarities, although there are also important differences. Table B enumerates all the UK and German industries in which RCA exceeds one in either or both of the periods 1970 to 1974 and 1990 to 1993. In the first of these two periods, industries in which the United Kingdom had a Revealed Comparative Advantage and Germany did not included Petroleum Refining, Non-Ferrous Metals, Aerospace, Other Manufacturing and Communication Equipment.

Table B also makes clear that industries in which an economy has an RCA change quite considerably over time. On the one hand, between the periods 1970 to 1974 and 1990 to 1993, the United Kingdom lost its RCA in Electrical machinery, Non-electrical machinery, Fabricated metal products and Non-ferrous Metals. On the other hand, the United Kingdom gained an RCA in Industrial Chemicals and Communication

---

(5) See the Appendix for further details concerning the data.

(6) As a result, one has to be careful when making direct comparisons of absolute values of RCA across economies. Suppose for example that the value of RCA in a particular sector in Germany exceeds the corresponding value in the United Kingdom. All that this tells one is that the ratio of the export share in that industry to the economy's *own* average export share in all manufacturing industries is higher in Germany than in the United Kingdom. RCA is informative because one can compare values across industries within an economy, with values of RCA greater than one denoting an industry in which an economy specialises. Examining the location of industries within an economy's own distribution of RCA informs about the economy's pattern of international specialisation. Comparing locations within distributions across economies, one acquires information about differences in the pattern of international specialisation. Analysing the evolution of each economy's distribution of RCA and movements in the location of industries within this distribution, one can then make statements about the dynamics of patterns of international specialisation and how these differ across economies.

Equipment.[7] In contrast, between the periods 1970 to 1974 and 1990 to 1993, Germany lost its RCA in a single industry (Computers), and gained an RCA in only one industry (Textiles and Footwear).

---

[7] In the period 1985 to 1989 (but not 1990 to 1993), the United Kingdom acquires an RCA in Shipbuilding. This is explained by a temporary rise in the United Kingdom's exports in the 'secrets' category of the shipbuilding sub-sector 'ships, boats (including hovercraft) and floating structures' (ISIC 793) for the years 1986 to 1990. This category includes 'warships of all kinds' and it is plausible that the United Kingdom's RCA in shipbuilding over this period reflects the large role played by government intervention in this sector. For this reason, the shipbuilding sector is excluded from the sample in the econometric analysis that follows. Nevertheless, all the empirical results that follow are not sensitive to its inclusion.

Table A: RCAM in the United Kingdom and Germany

Industry	ISIC Code	1970-1974		1975-1979		1980-1984		1985-1989		1990-1993	
		UK	Germany	UK	Germany	UK	Germany	UK	Germany	UK	Germany
Food, drink and tobacco	31	0.71	0.44	0.80	0.62	0.87	0.76	0.84	0.73	0.93	0.73
Textiles, footwear and leather	32	0.93	0.90	0.90	0.92	0.84	0.93	0.78	0.97	0.79	1.00
Wood, cork and furniture	33	0.22	0.63	0.35	0.80	0.32	0.79	0.28	0.86	0.29	0.80
Paper, print and publishing	34	0.54	0.51	0.58	0.61	0.62	0.77	0.62	0.85	0.80	0.90
Industrial chemicals	351+352-3522	0.96	1.32	1.04	1.30	1.16	1.37	1.16	1.35	1.17	1.28
Pharmaceuticals	3522	1.46	1.21	1.44	1.12	1.54	1.12	1.51	1.09	1.61	1.06
Petroleum refining	353+354	1.10	0.93	1.18	0.71	1.27	0.60	1.27	0.54	1.36	0.55
Rubber and plastic products	355+356	0.96	1.11	0.98	1.22	1.02	1.27	0.91	1.29	0.95	1.22
Stone, clay and glass	36	0.98	1.25	0.94	1.20	0.84	1.13	0.79	1.19	0.81	1.07
Ferrous metals	371	0.58	1.22	0.50	1.19	0.51	1.23	0.69	1.24	0.89	1.16
Non-ferrous metals	372	1.27	0.75	1.13	0.91	1.21	0.95	0.96	1.00	0.98	0.99
Fabricated metal products	381	1.12	1.42	0.98	1.38	0.96	1.34	0.83	1.48	0.82	1.41
Non-electrical machinery	382-3825	1.12	1.60	1.07	1.51	1.12	1.43	0.97	1.50	0.93	1.49
Computers and office machinery	3825	1.08	1.15	1.21	1.03	1.19	0.81	1.33	0.69	1.53	0.59
Electrical machinery	383-3832	1.03	1.47	0.96	1.47	0.99	1.36	0.86	1.37	0.84	1.37
Communication equipment	3832	0.72	0.98	0.77	0.96	0.72	0.82	0.77	0.76	1.02	0.73
Shipbuilding	3841	0.59	0.80	0.61	0.64	0.52	0.49	1.85	0.46	0.94	0.73
Other transport equipment	3842+3844+384	0.72	0.63	0.61	0.69	0.61	0.71	0.42	0.71	0.40	0.98
Motor vehicles	3843	0.94	1.45	0.78	1.41	0.62	1.56	0.48	1.47	0.67	1.42
Aerospace	3845	1.49	0.19	1.68	0.48	1.98	0.90	1.74	0.76	1.63	0.82
Instruments	385	1.00	1.25	0.97	1.16	1.15	1.07	1.09	1.09	1.07	1.09
Other manufacturing	39	2.48	0.77	2.50	0.66	1.93	0.59	1.85	0.61	1.57	0.62
Mean		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Standard Deviation		0.45	0.38	0.45	0.31	0.43	0.30	0.44	0.33	0.36	0.29

Table B

RCA in the UK and Germany

(*industries in which RCA is either acquired or lost over the sample period are denoted by italics*).

Country	Industry	**1970-74**	**1990-93**
UK	*Industrial Chemicals*	×	√
	Instruments	√	√
	Electrical Machinery	√	×
	Computers	√	√
	Petroleum Refining	√	√
	Non-electrical Machinery	√	×
	Fabricated Metal	√	×
	Non-ferrous Metals	√	×
	Pharmaceuticals	√	√
	Aerospace	√	√
	Other Manufacturing	√	√
	Communication	×	√
Germany	Rubber and Plastic	√	√
	Computers	√	×
	Pharmaceuticals	√	√
	Ferrous Metals	√	√
	Stone, Clay and Glass	√	√
	Instruments	√	√
	Industrial Chemicals	√	√
	Fabricated Metal	√	√
	Motor Vehicles	√	√
	Electrical Machinery	√	√
	Non-electrical Machinery	√	√
	Textiles & Footwear	×	√

Figures 2 to 6 characterise the evolution of the United Kingdom's pattern of international specialisation over time, an analysis that will be undertaken more formally in Section 4. In Figure 2, industries are ordered in terms of increasing RCA for the 1970 to 1974 period and the cross-section distribution of RCA for this time period graphed. In Figures 3, 4, 5 and 6, the same ordering of industries is preserved and the distribution of RCA plotted for the periods 1975 to 1979, 1980 to 1984, 1985 to 1989 and 1990 to 1993 respectively. Together, these Figures yield information concerning *intra-distribution dynamics*: if Revealed Comparative Advantage in the United Kingdom were characterised by substantial persistence, one would expect the distribution to look very much the same across successive time periods. Alternatively, if the United Kingdom were increasingly specialising in a subset of industries, one would expect to observe RCA systematically increasing and decreasing in certain sectors. In fact, what one appears to observe is considerable *mobility* in the United Kingdom's pattern of international specialisation, as evidenced by a comparison of Figures 2 and 6. This conclusion is supported by the (again informal) evidence in Table B of reversals of the United Kingdom's RCA in a number of specific sectors. A similar analysis may be undertaken for Germany. If industries are again ordered in terms of increasing RCA for the 1970 to 1974 period and the cross-section distribution of RCA in successive time periods graphed, the story again appears to be one of considerable mobility.

Figure 2:
UK RCA^M 1970-74

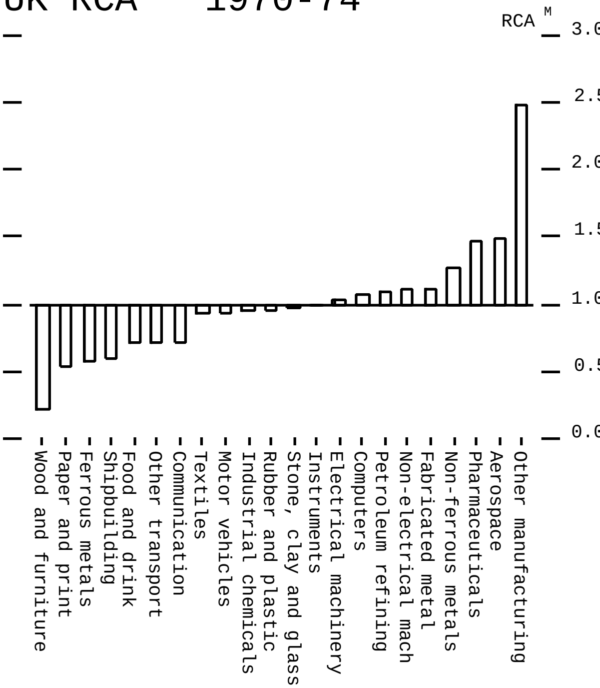


Figure 3:
UK RCA^M 1975-79

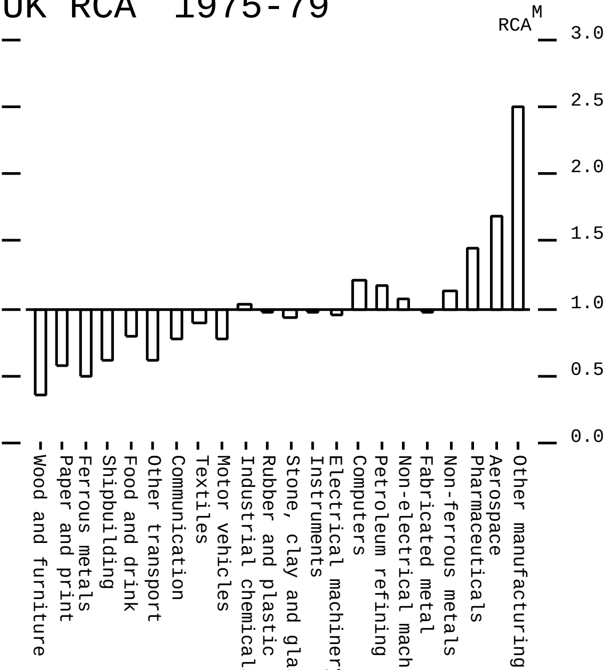


Figure 4:
UK RCA^{M} 1980-84

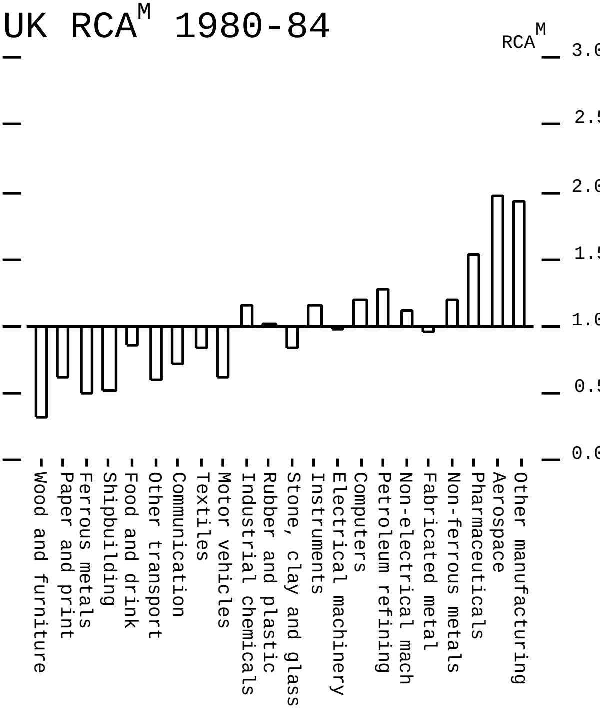


Figure 5:
UK RCA^{M} 1985-89

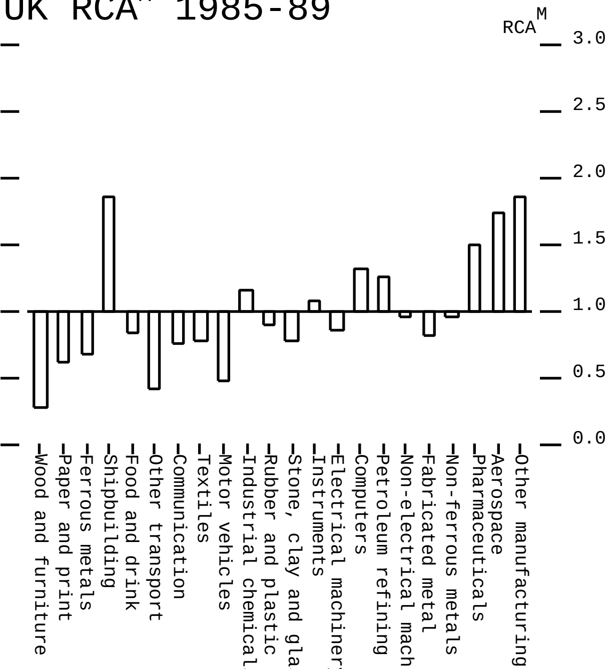


Figure 6:
UK RCA^M 1990-93

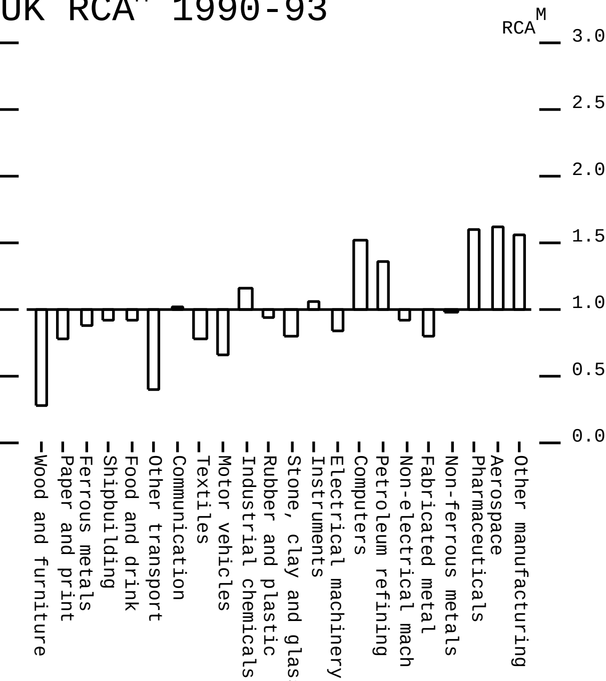
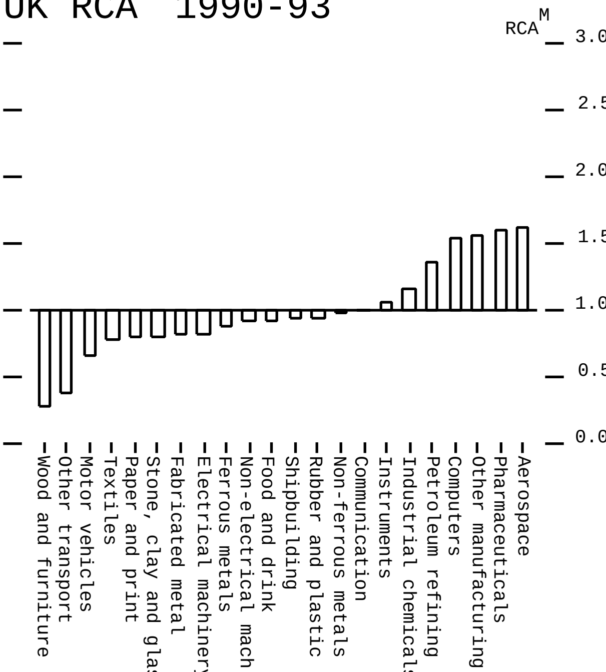


Figure 7:
UK RCA^M 1990-93



Similar graphical tools may be employed to characterise the evolution of the *external shape* of the distribution of Revealed Comparative Advantage. Figure 7 re-orders industries in the United Kingdom in terms of increasing RCA in the period 1990 to 1993 and plots the resulting cross-section distribution of RCA. Comparing Figures 2 and 7, it is clear that there is no systematic tendency for the United Kingdom to specialise increasingly in a limited subset of industries and the same is true for Germany. Over the sample period (from Table A), both economies experienced a decline in the dispersion of RCA as measured by the sample standard deviation, which, in itself, is suggestive of a decline in the extent of specialisation. In each of the sample sub-periods, the sample standard deviation is higher in the United Kingdom than in Germany, suggesting that the degree of specialisation is greater in the former than in the latter, exactly as one would expect given that the United Kingdom is the smaller economy.

4 Estimating distribution dynamics

The informal analysis of changing patterns of international specialisation above is now augmented with a formal model of distribution dynamics. Denote Revealed Comparative Advantage (RCA) by the measure x and its distribution across sectors at time t by $F_t(x)$. Corresponding to F_t, we may define a probability measure λ_t where $\forall\ x \in \Re$, $\lambda_t((-\infty, x]) = F_t(x)$. The evolution of the distribution of RCA over time is then modelled (following Quah (1993), (1996a) and (1996c)) in terms of a stochastic difference equation,

$$\lambda_t = P^*(\lambda_{t-1}, u_t), \qquad \text{integer } t \tag{7}$$

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. Even so, equation **(7)** is intractable and cannot be directly estimated. Setting the disturbances u to zero and iterating the stochastic difference equation forwards, we obtain,

$$
\begin{aligned}
\lambda_{t+s} = P^*(\lambda_{t+s-1}, 0) \quad &= P^*(P^*(\lambda_{t+s-2}, 0), 0) \\
&\;\vdots \\
&= P^*(P^*(P^* \ldots (P^*(\lambda_t, 0), 0) \ldots 0), 0) \\
&= (P^*)^s \lambda_t
\end{aligned} \tag{8}
$$

If the space of possible values of RCA is divided into a number of distinct, discrete cells, P^* becomes a stochastic matrix which may be estimated by counting the number of transitions out of and into each cell.[8] The output of this estimation process is a matrix P of transition probabilities p_{kl}, where p_{kl} denotes the probability that a sector moves from cell k to cell l. As a result, one is able to characterise the extent of mobility between different segments of the RCA distribution. Furthermore, by taking the limit $s \to \infty$ in equation **(8)**, one may obtain the implied ergodic RCA distribution. The latter provides information concerning the evolution of the external shape of the RCA distribution: whether, for example, the United Kingdom's pattern of international trade is polarising into two sets of sectors in which the economy exhibits increasing and decreasing specialisation or instead tends to remain roughly uniformly distributed around its mean value.

All empirical estimation was undertaken using Danny Quah's TSRF econometrics package,[9] and, in each case, the boundaries between cells were chosen such that industry-year observations are divided roughly equally between the grid cells. Table C presents estimates of the annual probability of transiting between different grid cells of the United Kingdom's distribution of RCA and Table D presents the corresponding estimates for Germany. In each case, the shipbuilding industry is excluded from the analysis as an outlier.[10]

The interpretation of these tables is as follows. The numbers in parentheses in the first column are the total number of industry-year observations beginning in a particular cell, while the first row of num-

[8] More generally, if we continue to treat RCA as a continuous variable, one may estimate the stochastic kernel associated with P^* (see for example Quah (1996c)). However, in the present application, there are too few cross-sectional units to permit such estimation.

[9] Responsibility for any results, opinions and errors is of course solely the authors'.

[10] However, the estimated transition probabilities are not greatly affected by its inclusion.

bers denotes the upper endpoint of the corresponding grid cell. Thereafter each row denotes the estimated probability of passing from one state into another. For example, the second row of numbers presents (reading across from the second to the fifth column) the probability of remaining in the lowest RCA state and then the probability of moving into the lower intermediate, higher intermediate and highest RCA states successively. The final row of the upper section of each Table gives the implied ergodic distribution, while, in the lower section of each Table, the one-year transition matrix is iterated five times.

Table C

Transition probabilities for the United Kingdom (one-year transitions)

United Kingdom		*Upper endpoint*		
Number	0.762	0.941	1.165	∞
(118)	0.92	0.08	0.00	0.00
(112)	0.06	0.79	0.14	0.00
(118)	0.00	0.17	0.72	0.11
(114)	0.00	0.00	0.11	0.89
Ergodic	0.213	0.289	0.243	0.255
	1 $\times$ transitions iterated 5 $\times$			
	0.6921	0.2315	0.0618	0.0086
	0.1736	0.4473	0.2623	0.0818
	0.0563	0.3186	0.3539	0.2609
	0.0078	0.0993	0.2609	0.6307

Estimated values of transition probabilities close to one along the diagonal are indicative of persistence in either the United Kingdom or Germany's pattern of RCA, while large off-diagonal terms imply greater mobility. The results of both Tables C and D suggest a relatively high degree of *mobility* in patterns of international specialisation in both countries: a finding that is consistent with the visual evidence presented earlier.

Table D
Transition probabilities for Germany (one-year transitions)

Germany	*Upper endpoint*			
Number	0.738	1.006	1.258	∞
(116)	0.88	0.12	0.00	0.00
(116)	0.11	0.83	0.06	0.00
(116)	0.00	0.06	0.88	0.06
(114)	0.00	0.00	0.07	0.93
Ergodic	0.245	0.264	0.264	0.227
	1 $\times$ transitions iterated 5 $\times$			
	0.6137	0.3360	0.0470	0.0034
	0.3080	0.4972	0.1699	0.0249
	0.0431	0.1699	0.5817	0.2053
	0.0036	0.0291	0.2395	0.7279

For example, in the United Kingdom the probability of moving out of one grid cell after one year ranges from 8%-28%. Iterating the one-year transition matrix five times, this result is brought out more strongly: the probability of remaining in the same cell over the five-year period ranges from 69% to only 35%. The results for Germany are broadly similar, although the matrix of transition probabilities is generally characterised by larger diagonal terms and smaller off-diagonal entries, suggesting that the United Kingdom's pattern of international specialisation is characterised by greater mobility than Germany's.

In order to consider this latter hypothesis more formally, Table E calculates a variety of indices of mobility (following Shorrocks (1978), Geweke, Marshall and Zarkin (1986) and Quah (1996b)) for the United Kingdom and Germany. Each of these indices attempts to reduce information about mobility from the matrix of transition probabilities P to a single statistic. Thus, M_1 evaluates the trace (tr) of the matrix, M_4 analyses the determinant (det), M_3 and M_5 are based on the eigenvalues ξ_j of the matrix, while M_2 presents information on the average number of class boundaries crossed by an individual originally in state k weighted by the corresponding proportions π_k of the ergodic distribution. In each case, the mobility index for the United Kingdom exceeds that for Germany.[11]

[11] For the exact relationship between these indices and the circumstances under which they yield transitive rankings of transition probability matrices see Shorrocks

Table E: Mobility Indices for the United Kingdom and Germany

	Index	**UK**	**Germany**
Shorrocks (1978)	$M_1 = \frac{n-tr[P]}{n-1}$	0.227	0.160
Bartholomew, Shorrocks (1978)	$M_2 = \sum_k \pi_k \sum_l p_{kl} \lvert k-l \rvert$	0.171	0.122
Geweke *et al.* (1986), Quah (1996b)	$M_3 = \frac{n-\sum_m \lvert \xi_m \rvert}{n-1}$	0.227	0.160
Shorrocks (1978)	$M_4 = 1 - \lvert \det(P) \rvert$	0.566	0.419
Geweke *et al.* (1986), Quah (1996b)	$M_5 = 1 - \lvert \xi_2 \rvert$	0.689	0.432

While these empirical results constitute suggestive evidence that the United Kingdom's pattern of international specialisation is more mobile than Germany's, it would be useful to obtain information concerning the statistical significance of these findings. In this regard, we make use of the results relating to the asymptotic properties of first-order Markov Chains in Anderson and Goodman (1957). The latter show that, for each state k, under the null hypothesis $p_{kl} = \tilde{p}_{kl}$,

$$\sum_{l=1}^{m} n_k^* . \frac{(p_{kl} - \tilde{p}_{kl})^2}{\tilde{p}_{kl}} \sim \chi^2(m-1), \qquad n_k^* \equiv \sum_{t=0}^{T-1} n_k(t) \tag{9}$$

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. The test statistic in **(9)** cannot be used to directly test the hypothesis that, for each state k, the transition probabilities estimated for the United Kingdom are equal to those estimated for Germany (since, in this case, both sets of transition probabilities are estimates,[(12)]). Nonetheless, suppose that we adopt as the null the hypothesis that the Data Generating Process (DGP) underlying the United Kingdom's pattern of Revealed Comparative Advantage is the estimated matrix of German transition probabilities.

(1978) and Geweke *et al.* (1986).

[(12)] To test this hypothesis, one would need to impose a theoretical prior concerning the process determining the evolution of Revealed Comparative Advantage (since the variance of each set of estimates will be a function of this prior.) This is precisely something that we wish to avoid at this stage of the analysis: we wish to *characterise* the dynamics of international specialisation without imposing any theoretical restrictions on the data.

We may then test whether the transition probabilities estimated for the United Kingdom are (or are not) statistically significantly different from those of the null ($p_{kl}^{UK} = \tilde{p}_{kl}^{G}$). Similarly, for Germany, one may test whether the estimated transition probabilities are statistically significantly different from the null that the DGP is the UK matrix of transition probabilities ($p_{kl}^{G} = \tilde{p}_{kl}^{UK}$).

These tests may be undertaken for each state $k = 1, ..., m$. Furthermore, since the transition probabilities are independently distributed across states k, we may sum over states in **(9)** and test the hypothesis that, for *all* states $k = 1, ..., m$, the estimated transition probabilities are equal to those under null. The resulting test statistic is asymptotically distributed $\chi^2(m(m-1))$. Implementing this test for each of the two hypothesis outlined above, the null is rejected at both the 95% and 99% confidence level.

Thus, the empirical analysis of this section has sought to characterise the degree of persistence and mobility in patterns of international specialisation in the United Kingdom and Germany over the period 1970 to 1993. The degree of mobility estimated in the United Kingdom was found to exceed that in Germany. Although it was not possible to test directly whether the estimated transition probabilities were statistically significantly different, it was possible to test a related hypothesis. Namely, for each country, we tested whether the estimated transition probabilities were statistically significantly different from the null that they were generated by a DGP characterised by the other country's (estimated) matrix of transition probabilities. In each case, the null was rejected at the 99% confidence level.

In order to test the robustness of these results, the matrix of transition probabilities was re-estimated in two ways. First, the space of values of RCA was divided into five cells rather than four and, second, the transition probabilities were estimated allowing transitions to occur over five-year rather than one-year periods. The probabilities estimated over five-year transition periods do differ from the one-year transition probabilities iterated five times, suggesting that the evolution of RCA is not fully characterised by a first-order, time homogenous model. Nonetheless, in both cases, the results suggested a broadly similar interpretation to that given above and, in particular, the finding that the United Kingdom's pattern of international specialisation is characterised by greater mobility was preserved.

In each of the two countries, the implied ergodic distribution of

RCA in Tables C and D is approximately uniform and there is *no* evidence that the pattern of specialisation is polarising into two sets of sectors where an economy is characterised by systematically increasing and decreasing degrees of specialisation.

5 Conclusion

International trade dynamics have received relatively little attention in the existing empirical literature. This paper is concerned with the evolution of international specialisation across 22 manufacturing industries in the United Kingdom and Germany over the period 1970 to 1993. Although the paper is largely empirical, the analysis is motivated with a simple theoretical model of international trade and endogenous growth. Sector-specific learning by doing is a force towards persistence in patterns of international trade, while technology transfer engenders mobility. Variations in exogenous rates of productivity growth across sectors may be responsible for either persistence or mobility.

Whether actual patterns of international trade exhibit persistence or mobility will depend upon the net outcome of these (and possibly other) forces. The empirical analysis in this paper seeks to *characterise* the extent of persistence and mobility in UK and German patterns of international trade, leaving the explanation of observed trade dynamics (in terms of, for example, learning by doing and technology transfer) to further work.

An empirical measure of the extent of international specialisation in individual manufacturing sectors was presented, based upon Balassa (1965)'s concept of RCA. The dynamics of international specialisation were then modelled in terms of the evolution of the entire cross-section distribution of RCA. Instead of exhibiting persistence, international trade patterns were found to be characterised by a surprising degree of mobility. The degree of mobility in the United Kingdom (as measured by formal indices of mobility) was found to exceed that observed in Germany. In neither economy was there evidence of an increase in the degree of specialisation over the sample period.

6 Appendix: data

The data source for the indices of Revealed Comparative Advantage is the OECD's Bilateral Trade Database (BTD). This provides information on the value of exports and imports between the 23 OECD countries and 15 partner economies. The partner countries are: Argentina, Brazil, China, Czech and Slovak Republics, Hong Kong, Hungary, India, Indonesia, Malaysia, Mexico, Philippines, Singapore, Korea (South), Taiwan and Thailand. Although OECD imports from and OECD exports to these partner countries are included in the database, trade entirely outside the OECD area (eg from one partner country to another) is not. The OECD estimates that 90%-95% of world trade in goods is included in the database.

References

Anderson, T, W, and Goodman, L, A, (1957) 'Statistical Inference about Markov Chains', *Annual of Mathematical Statistics*, XXVIII.

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

Bernard, A and Jones, C (1994) 'Comparing Apples to Oranges: Productivity, Convergence and Measurement across Industries and Countries', *MIT Working Paper*, No 94-12.

Bernard, A and Jones, C (1996) 'Productivity Across Industries and Countries: Time Series Theory and Evidence', *Review of Economics and Statistics*, February, pages 135-46.

Coe, D and Helpman, E (1995) 'International R & D Spillovers', *European Economic Review*, vol 39, pages 859-87.

Dornbusch, R, Fischer, S and Samuelson, P (1977) 'Comparative Advantage, Trade and Payments in a Ricardian Model with a Continuum of Goods', *American Economic Review*, December, pages 823-38.

Geweke, J, Marshall, R and Zarkin, G (1986) 'Mobility Indices in Continuous Time Markov Chains', *Econometrica*, vol 54, no 6, November, pages 1,407-23.

Grossman, G and Helpman, E (1991) *Innovation and Growth in the Global Economy*, MIT 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.

Lucas, R, E (1993) 'Making a Miracle', *Econometrica*, March, pages 251-72.

Quah, D, T, (1993) 'Empirical Cross-Section Dynamics in Economic Growth', *European Economic Review*, vol 37, pages 426-34.

Quah, D, T, (1996a) 'Twin Peaks: Growth and Convergence in Models of Distribution Dynamics', *Economic Journal*, July, pages 1,045-55.

Quah, D, T, (1996b) 'Aggregate and Regional Disaggregate Fluctuations', *Empirical Economics*, vol 21, pages 137-59.

Quah, D, T, (1996c) 'Convergence Empirics Across Economies with (some) Capital Mobility', *Journal of Economic Growth*, March, pages 95-124.

Redding, S (1996) 'Dynamic Comparative Advantage and the Welfare Effects of Trade', Nuffield College, Oxford, Paper Presented at the European Economic Association Conference 1996.

Shorrocks, A, F (1978) 'The Measurement of Mobility', *Econometrica*,
vol 46, no 5, September, pages 1,013-24.