TEL-AVIV

WP 4-96

The Foerder Institute
for Economic Research

Tel Aviv University
The Eitan Berglas School of Economics

מכון למחקר כלכלי ע"ש ד"ר ישעיהו פורדר

הפקולטה למדעי החברה אוניברסיטת תל-אביב

TECHNOLOGICAL CONVERGENCE AND INTERNATIONAL TRADE

by

Dan Ben-David[1] and Atiqur Rahman[2]

Working Paper No.4-96

January, 1996

[1] The Eitan Berglas School of Economics, Tel-Aviv University, Ramat Aviv, Tel-Aviv 69978 and CEPR. E-mail: BenDavid@econ.tau.ac.il.
[2] University of Houston

THE FOERDER INSTITUTE FOR ECONOMIC RESEARCH
Faculty of Social Sciences
Tel-Aviv University, Ramat Aviv, Israel.

ABSTRACT

This paper builds on earlier evidence showing that, while most countries exhibit little evidence of unconditional income convergence, countries that trade heavily with one another tend to exhibit a much higher incidence of convergence. Two alternative explanations for the trade-related convergence are explored here. The first alternative is that the trade-related income convergence is due to a convergence in capital-labor ratios. Little support is found for this explanation. The other alternative examined here is that of a trade-related convergence in technologies. This alternative is corroborated by a high incidence of convergence in total factor productivities among countries that trade heavily with one another - an outcome that is not common between these same countries when they are grouped randomly rather than on the basis of trade.

I. INTRODUCTION

The relationship between trade and technology is a question that has been discussed for quite a number of years. While the traditional trade literature tended to focus on this issue from the perspective of the impact of technological progress on trade, recent advances in the endogenous growth literature have shifted the emphasis towards trade's contribution to the growth process.[1] This paper continues along the latter vein under the premise that openness to trade induces competition that compels domestic firms to imitate and innovate, and in so doing, to increase domestic knowledge stocks and propel growth.

The paper builds upon earlier studies by Ben-David which examined the predilection towards convergence and the proclivity towards divergence of various countries, as well as the link between trade relationships and the behavior of cross-country income gaps over time. In light of the earlier findings, the contribution of this paper is in the identification of a channel through which strong trade relationships might lead to income convergence. In particular, the focus here is on capital-labor ratios and total factor productivities (which are assumed here to proxy for the intangible we call technology) in an attempt at identifying which of these components in the aggregate production function is most affected by trade – and subsequently most influential in reducing the income gaps that exist between countries.

As Romer (1986) and Lucas (1988) observed in their seminal papers, income gaps between most countries in the world show little evidence of falling over time. If anything, the opposite seems to be the case. In the case of the more developed countries, however, Baumol

---

[1] For recent discussions of the trade-technology relationship, see Rivera-Batiz and Romer (1991), Grossman and Helpman (1995), and others.

(1986), Dowrick and Nguyen (1989) and others have found evidence of income and TFP convergence.

Just who is converging with whom? By grouping and regrouping 112 countries into thousands of different sub-combinations, Ben-David (1994a) finds that there is a higher incidence of convergence at both ends of the income spectrum. In contrast to the conventional wisdom, the highest incidence of convergence is among the very poorest countries. There is also evidence of convergence among the wealthier countries, but this is far from a robust finding. In fact, a random sub-grouping of wealthy countries is more than likely *not* to exhibit significant convergence. So, if a high level of development is insufficient for deducing convergence, could there be other defining characteristics of countries that converge?

One theoretical framework that has been associated with the equalization of incomes is the Heckscher-Ohlin theory, and in particular, the factor-price equalization proposition (Samuelson, 1948; Helpman and Krugman, 1985) which postulates that, when certain restrictions apply, free trade should bring about an equalization of commodity and factor prices. Alternatively, the neoclassical growth model (Solow, 1956) explains convergence in per capita incomes without any reference to international trade. Under the assumption of identical and exogenous technological progress across nations, unhindered capital flows from rich to poor countries facilitate the convergence process by bringing about an equalization of capital-labor ratios, and subsequently, of incomes as well.

But, as Lucas (1990) points out, the international flow of capital is much smaller than theory predicts. In some of the more recent growth literature, which endogenizes the growth process, trade facilitates the diffusion of knowledge (see for example: Grossman and Helpman, 1994; Eaton and Kortum, 1995). This conclusion is supported by the empirical findings of knowledge spillovers between trade partners in Coe, Helpman, and Hoffmaister (1995) and Keller (1995), as well as Helliwell's (1992) finding of a positive relationship between trade and technological progress.

However, while there is evidence that trade affects growth, does trade also play a role in the convergence of incomes? In an attempt to determine the causality of the relationship between trade and income convergence, Ben-David (1993 and 1994b) examined several instances of explicit trade liberalization that was carried out along specific timetables. In these studies, it is shown that countries whose income differentials had remained more or less constant for over half of a century began to exhibit convergence just as they began to liberalize trade. At the end of each of the liberalization processes, income differentials continued to remain at their new, low, levels for the remaining decades of the sample. The studies also show that these episodes of convergence were not evident in benchmark comparisons of non-liberalizing countries.

One of the by-products of this research was the finding that trade liberalization is conducive to income convergence only if the trade reform is being carried out by major trade partners. With this in mind, Ben-David (1996) focused on exactly those countries at the upper end of the income spectrum of the earlier (1994a) study which exhibit some evidence of convergence, though as noted above, this is the exception rather than the rule. The objective of the 1996 study was to identify the primary trade partners of each of the top 25 countries (in terms of levels of development) and to test for convergence within each of these trade-based groups. While the majority of the trade-based groups exhibited income convergence, alternative groupings (made randomly) from the same pool of countries showed no convergence tendencies whatsoever.

The goal of the following sections is to expand on these findings and examine if the convergence in the trade-based groups corresponded with convergence in capital-labor ratios, or alternatively, whether it corresponded with convergence in total factor productivity levels. Section two describes how the trade groups were constructed and details the methodology that will be used to determine convergence. The relationship between trade and capital-labor ratios is examined in section three. A simple model describing how knowledge spillovers facilitated by trade can lead to convergence in output per worker is detailed in section four. This is then followed by an empirical examination of the trade-technology relationship in section five. Section six concludes.

II. THE SETUP AND THE CONVERGENCE MODEL

The trade-based groups examined here are the same groups created in Ben-David (1996) according to the following criteria. Each group is formed for a specific "source" country on the basis of that country's external trade. Source countries are all of the non-Communist and non-primary-oil producing countries that had per capita incomes that were at least 25% of the U.S. income in 1960, the first year of the sample. There are 25 countries that satisfy this criteria and also list bilateral trade data continuously between the years 1960 and 1985, the final year of the sample. IMF Direction of Trade statistics were used to determine which countries were the primary recipients of each source country's exports, thereby creating a group of primary export partners for each source country. Similarly, a group of primary import partners was also formed for each source country.[2] The resultant export and import-based groups (25 of each: one per source country) range in size from 3 to 9 countries per group. A detailed list of group members may be found in appendix Table A1.

The common method for determining convergence is to calculate each country's average growth rates over a period and to regress these on the respective country's initial levels of income as well as on additional variables that one wishes to control for. The relatively small number of countries in each group precludes the use of this test since the number of observations would be extremely small. In addition, by utilizing only the initial and terminal data points for each output series, the conventional convergence test wastes a considerable amount of information. An alternative method is used in Ben-David (1993, 1994a and 1996) which follows Hotelling's (1933) view that convergence should be characterized by the reduction in income differentials over time.

The convergence model is as follows. Let $x_{i,t}$ be the value (in logs) of the variable of interest of country i at time t and let $\bar{x}_t$ be the group's average at time t (where $\bar{x}_t$ is the mean of the $x_{i,t}$'s). Then the average rate of convergence for each group is found by calculating the difference between each $x_{i,t}$ and $\bar{x}_t$, pooling the countries, and regressing these differences on lagged differences, *i.e.*

[2] Additional details on the construction of the export and import-based groups may be found in Ben-David (1996).

$$(x_{i,t} - \bar{x}_t) = \phi(x_{i,t-1} - \bar{x}_{t-1}) + \varepsilon_{i,t} \quad . \qquad (1)$$

As a result of the pooling, the dependant and independent variables have a zero mean over all the countries and years, hence there is no intercept term in equation 1.[3] Divergence is indicated when the estimated ϕ is above unity, while a sub-unity ϕ indicates convergence.

Defining $z_{i,t} = x_{i,t} - \bar{x}_t$, then equation (1) becomes a unit root test of the variable z, hence the augmented-Dickey-Fuller (ADF) form of the equation will be estimated, which in this case is

$$z_{i,t} = \phi z_{i,t-1} + \sum_{j=1}^{k} c_j \Delta z_{i,t-j} + \varepsilon_{i,t} \qquad (2)$$

where $\Delta z_{i,t} = z_{i,t} - z_{i,t-1}$. As Quah (1994) points out, in the event of pooling, as is the case here, the t-statistic behaves as if it were normal asymptotically. Indeed, Levin and Lin (1992) calculate critical t-values for such pooled equations which exclude drift and trend and find that these are nearly identical to the standard t-values.

Estimations of equation (2) for per capita incomes in Ben-David (1996) indicate a preponderance of sub-unity ϕ's in the export and import-based groups. All but one of the 25 ϕ's in the export groups was sub-unity (14 of these were significantly so at the 5% level) and 22 of the 25 import groups' ϕ's were sub-unity (17 of these were significantly so at the 5% level). In contrast, when these same countries that comprise the trade groups were grouped randomly, rather than on the basis of trade, there were more divergence outcomes than convergence ones.

[3] See Ben-David (1996).

So what is the source of this trade-related convergence? If one assumes that output per worker (y) is a monotonically increasing function of physical capital per worker (k), then could the convergence in the y's be coming from a convergence in the k's? That is the focus of the following section.

III. Capital-Labor Ratios and Trade

Rather than use real GDP per capita, as was the case in Ben-David (1996), the emphasis here will be on real GDP per worker (Y/L) which is more closely related to the dependant variable in the neoclassical growth model. The source of this data is Summers and Heston (1995), who use purchasing power parities (which facilitate cross-country comparisons) rather than exchange rates. Data on real aggregate capital stocks (K), denoted in constant domestic currency, comes from the World Bank and is described by Nehru and Dhareshwar (1993). To convert this data into internationally comparable capital per worker (K/L) using Summers and Heston's purchasing power parities, the aggregate capital stocks are multiplied by the ratio of real GDP per worker from Summers and Heston to real aggregate GDP denoted in domestic currency from the World Bank (1994).

Presumably, if output production can be described by

$$y = Ak^{\beta} \quad . \tag{3}$$

then the implication that the y's are a function of the k's should be borne out by the data as well. And, in fact, the cross-country correlation coefficient between the log of per capita outputs and the log of capital-labor ratios in the first and last years of the sample is 0.95 in both instances.

Before proceeding to an analysis of k convergence within the trade groups, it is interesting to note the incidence of k convergence in general between the countries.[4] This will provide a reference point from which it will be possible to determine the uniqueness of the trade group results.

Since the average number of countries in the trade-based groups is six, suppose that groups consisting of six countries are created from the pool of 25 source countries plus 6 additional major trade partners.[5] There are 736,281, or 31!/(6!25!), different possibilities for grouping the 31 countries into groups of 6. To keep the analysis within reasonable proportions, 5000 different random groupings of the countries were performed and each group's ϕ was estimated using equation (2). This was done for both the k's and the y's. In the case of the capital-labor ratios, 20% of the ϕ_k's are significantly below unity – indicating convergence – at the 5% level. In the case of the y's, 21% of the ϕ_y's are significantly below unity at the 5% level.

How closely do the trade group estimations resemble these proportions? Table 1 lists the results of the estimations for both the export-based and the import-based groups. The source countries of each group are listed in the left column of each panel. The column to the right of the source countries lists the number of countries in each group. The next two columns display the estimated convergence coefficients of the y's and their respective t-statistics for testing the null that ϕ equals unity (the groups are sorted by these t-statistics).

---

[4] Cohen (1995), for example, finds that while per capita incomes are not converging worldwide, there does appear to be evidence of a global convergence in capital stocks.

[5] Most of the primary trade partners tend to be countries that are also source countries. In some instances however, there are additional, non-source, countries that are also primary trade partners. Altogether, the pool of countries includes 32 countries (including the 25 source countries). Since there are no capital stock data for the Congo, which is a primary partner in South Africa's trade group, the focus in this paper will be on the 31 remaining countries.

One of the first findings here is that the use of output *per worker* considerably sharpens the earlier convergence results from Ben-David (1996) which were based on output *per capita*. Of the 25 export-based groups, 22 (or 88% of the groups) exhibit significant convergence at the 5% level (compared to just 14 in the earlier study). In the case of the import-based groups, 21 of the 25 groups exhibit significant convergence at the 5% level (compared to 17 in the earlier study).[6]

What about the capital-labor ratios? As both panels of the table indicate, there is very little evidence of convergence in the k's, with just 3 of the export-based groups – 4 of the import-based groups – exhibiting significant (at the 5% level) convergence. In other words, the likelihood of finding convergence in k's within a trade-based group is no greater than the likelihood of finding convergence within a random grouping of countries. Thus, if the trade-related convergence in outputs is not a result of convergence in the capital-labor ratios, it becomes necessary to examine an alternative source of convergence.

IV. KNOWLEDGE FLOWS AND TRADE

Since the above section indicates no particular propensity towards convergence in the k's, and if the production function is of the type specified in equation (3), then the source of the convergence must be in the technology factor A. The question then is, why should trade lead to a convergence in technologies?

[6] Ben-David (1996) shows that the sensitivity of the convergence results to the inclusion or exclusion of individual countries (such as the United States, Germany, Japan and the United Kingdom) in the different trade-based groups does not appreciably alter the final outcomes.

Ben-David and Loewy (1995) develop a theoretical framework that follows Romer (1986) by abstracting from physical capital and focusing on the importance of knowledge in production.[7] While the majority of recent modeling frameworks focus on the microeconomic channels through which international trade induces competition, the objective in the model described below is more limited. Given the aggregate nature of the trade data involved, the goal is to describe a simple aggregative model that uses bilateral trade volumes (which served as the basis for the construction of the trade groups) as a conduit for the dissemination of ideas and shows how this process can be an equilibrating force between countries.

Following Grossman and Helpman (1991 and 1995), the premise here is that trade is a channel for knowledge spillovers. Rather than focusing on the contribution of trade to steady state growth, which has generally been the primary emphasis in the recent growth-related literature, the BL model is simplified here so as to maintain the focus on trade's contribution to the process of income convergence between countries.

It is assumed that each of J countries produces a distinct good, with country i producing good i. Output growth results from the accumulation of knowledge, while capital is constant and normalized to equal unity. The production function is linear homogeneous in labor, hence output per worker in country i may be expressed as

$$y_i(t) = H_i(t)^{\varepsilon} \tag{4}$$

where $H_i(t)$ is the aggregate stock of knowledge in country i at time t.

Accumulation of knowledge in country i is given by

---

[7] In contrast with Romer however, the BL model focuses on the aggregate stock of knowledge in the economy while Romer distinguishes between this aggregate stock and firm-specific knowledge.

$$\dot{H}_i(t) = \theta\left[H_i(t) + \sum_{j \neq i} v_{ij}(t) H_j(t)\right] \tag{5}$$

where θ represents the productivity parameter common to all countries and v_{ij} is the ratio of country i's total exports to country j divided by country i's aggregate output, or

$$v_{ij}(t) = \frac{L_j(t)\, c_{ji}(t)}{L_i(t)\, y_i(t)} \quad , \qquad i \neq j$$

where c_{ji} represents country j's real per capita consumption of country i's goods and L_i is the size of the labor force in country i at time t.

Thus, domestic knowledge accumulation is dependent not only on the stock of domestic knowledge, but also on the stock of knowledge in the country's trade partners, as well as on the extent of trade that exists between the countries. The v_{ij} term incorporates Grossman and Helpman's notion that knowledge spillovers increase with the volume of trade.

Consumer preferences in country i are given by

$$\int_0^\infty e^{-(\rho - n)t} L_i(0) \sum_{j=1}^{J} \alpha_{ij} \ln c_{ij}(t)\, dt \tag{6}$$

where n is the rate of population growth (initial population levels in each country will be normalized to equal unity), ρ is the rate of time preference, and $0 < \alpha_{ij} < 1$ ensures trade in the model ($\sum_{j=1}^{J} \alpha_{ij} = 1$). Country i's income is used to finance the consumption of both domestic and foreign goods, in other words

$$\sum_{j=1}^{J} \frac{p_j(t)}{p_i(t)} c_{ij}(t) = H_i(t)^{\varepsilon_i}$$

where $p_i(t)$ is the time t price of good i (good 1 is the numeraire good) and assuming that there are no restrictions on trade. While trade need not be bilaterally balanced, the absence of international capital flows in the model implies that each country's overall trade must be balanced, *i.e.*

$$L_i(t) \sum_{j \neq i} p_j(t) c_{ij}(t) = \sum_{j \neq i} p_i(t) L_j(t) c_{ji}(t) \qquad \forall\, i \ .$$

When taken in the global context, equation (5) constitutes a dynamic system of equations that can be described in vector notation by $\mathring{\mathbf{H}}=\mathbf{\Omega H}$. As is shown in BL, $\mathbf{\Omega}$ is a matrix of constants, hence the solution to this system of equations is

$$\mathbf{H}(t) = \sum_{j=1}^{J} \xi_j e^{\mu_j t} \mathbf{x}_j \tag{7}$$

where the μ_j's are the eigenvalues of $\mathbf{\Omega}$, the $\mathbf{x}_j$'s are their associated eigenvectors, and the ξ_j's are constants determined by the initial conditions.

Suppose that $\alpha_{ij}=\alpha_{ji}=\alpha$, then in the two country case we get $\nu_{12}=\nu_{21}=\nu=\alpha$ which is constant. Hence, the solution in (7) can be written as

$$\begin{aligned} H_1(t) &= H_1(0) e^{\theta(1+\nu)t} + H_2(0) e^{\theta(1-\nu)t} \\ H_2(t) &= H_1(0) e^{\theta(1+\nu)t} - H_2(0) e^{\theta(1-\nu)t} \end{aligned} \tag{8}$$

where $H_1(0)$ and $H_2(0)$ are the initial values of knowledge stocks in the two countries. Letting $\tilde{H}_i$ be the log of H_i and $\tilde{H}$ be the average of $\tilde{H}_1$ and $\tilde{H}_2$, then

$$\tilde{H}_1(t) - \bar{H}(t) = 0.5\log\left(\frac{H_1(0)e^{\theta(1+v)t} + H_2(0)e^{\theta(1-v)t}}{H_1(0)e^{\theta(1+v)t} - H_2(0)e^{\theta(1-v)t}}\right) \tag{9}$$

Given the relationship between y and H expressed in equation (4), then the behavior of the gap $\tilde{H}_1$-$\bar{H}$ reflects the behavior of the gap $\tilde{y}_1$-$\bar{y}$ which, in this form, constitutes the basis of convergence equation (1).

Note that the y in this model may be interpreted as the technology factor A in equation (3) since it abstracts from the physical capital stock. Since both the numerator and the denominator on the right-hand-side of (9) tend to $H_1(0)e^{\theta(1+v)t}$ as t goes to infinity, then the implication is that the gap on the left-hand side goes to zero and that the technologies should converge over time.

V. TECHNOLOGY CONVERGENCE

To estimate the rate of convergence in technologies, it is possible to calculate the total factor productivities (TFP), or A in equation (3), for each of the countries. Following Coe, Helpman and Hoffmaister (1995), the parameter β is chosen to be 0.4. Since most economists tend to place the value of β between 0.3 and 0.4, the following estimations were run for $\beta=0.3$ as well.

As before, a benchmark reference point for TFP convergence among all of the countries in the sample will be useful for determining the uniqueness of the results from the trade groups. Hence, 5000 random groupings from the entire set of 31 countries are drawn and equation (2) is estimated for each of the groups. When β=0.4, then 17% of the groups exhibit significant convergence at the 5% level. This percentage increases slightly to 20% when β is set at 0.3.

As is indicated in Table 2, when β=0.4, then 15 of the 25 export-based groups (13 of the import-based groups) exhibit significant convergence at the 5% level. When β is lowered to 0.3, 23 of the 25 export-based groups and 20 of the import-based groups exhibit TFP convergence.

VI. CONCLUSION

Countries in randomly created groups tend to display very little evidence of income convergence between them. On the other hand, when international trade is used as the basis for grouping countries, there tends to be a relatively high incidence of income convergence among the heavy traders. This result is verified here and is shown to be even stronger when output per worker is used, rather than output per capita.

The primary focus of this paper however, is to determine whether it is a convergence in capital-labor ratios that is behind the trade-related income convergence, or whether the primary source of the income convergence comes from a convergence in technologies. Capital-labor ratios in the trade-based groups display no particular convergence tendencies above what can be expected from a random drawing of countries.

In contrast with the capital-labor results, grouping countries according to their primary trade partners appears to produce substantial evidence of technological convergence among the countries. To the extent that output per worker in these trade-based groups has also converged to a much greater extent than is evident in random country groupings, it would appear that the mechanism through which trade leads to convergence is via the technology route.

References

Baumol, William J. (1986), "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show," *American Economic Review*, *76*, 1072-85.

Ben-David, Dan (1993), "Equalizing Exchange: Trade Liberalization and Income Convergence," *Quarterly Journal of Economics*, *108*, 653-79.

Ben-David, Dan (1994a), "Convergence Clubs and Diverging Economies," CEPR Discussion Paper No. 922.

Ben-David, Dan (1994b), "Income Disparity Among Countries and the Effects of Freer Trade," *Economic Growth and the Structure of Long Run Development*, in Luigi L. Pasinetti and Robert M. Solow (eds.), London: Macmillan, 45-64.

Ben-David, Dan (1996), "Trade and Convergence Among Countries," forthcoming: *Journal of International Economics*.

Ben-David, Dan and Michael B. Loewy (1995), "Free Trade and Long-Run Growth," CEPR Discussion Paper No. 1183.

Coe, David T., Elhanan Helpman, and Alexander W. Hoffmaister (1995), "North-South R&D Spillovers," NBER Working Paper No. 5048.

Cohen, Daniel (1995), "Tests of the Convergence Hypothesis: Some Further Results," CEPR Discussion Paper No. 1163.

Dowrick, Steve and Duc-Tho Nguyen (1989), "OECD Comparative Economic Growth 1950-85: Catch-Up and Convergence," *American Economic Review*, *79*, 1010-30.

Eaton, Jonathan and Samuel Kortum (1995), "Trade in Ideas: Patenting and Productivity in the OECD," NBER Working Paper No. 5049.

Grossman, Gene and Elhanan Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge: MIT Press.

Grossman, Gene M. and Elhanan Helpman (1995), "Technology and Trade," in *Handbook of International Economics, vol. III*, in G. Grossman and K. Rogoff (eds.), Amsterdam: Elsevier Science Publishers, 1279-1337.

Helliwell, John F. (1992), "Trade and Technical Progress," NBER Working Paper No. 4226.

Helpman, Elhanan and Paul R. Krugman (1985), *Market Structure and Foreign Trade*, Cambridge: MIT Press.

Hotelling, Harold (1933), "Review of *The Triumph of Mediocrity in Business*, by Horace Secrist," *Journal of the American Statistical Association*, *28*(184), 463-65.

International Monetary Fund, *Direction of Trade Statistics Yearbook*, Washington, D.C., various editions.

Keller, Wolfgang (1995), "Trade and the Transmission of Technology," unpublished working paper.

Levin, Andrew and Chien-Fu Lin (1992), "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties," University of California - San Diego Discussion Paper 92-23.

Lucas, Robert E., Jr. (1988), "On the Mechanics of Economic Development," *Journal of Monetary Economics*, *22*, 3-42.

Lucas, Robert E., Jr. (1990), "Why Doesn't Capital Flow from Rich to Poor Countries?," *American Economic Review*, *80*, 92-96.

Nehru, Vikram and Ashok Dhareshwar (1993), "A New Database on Physical Capital Stock: Sources, Methodology and Results," World Bank Working Paper.

Quah, Danny (1994), "Exploiting Cross-Section Variation for Unit Root Inference in Dynamic Data," *Economic Letters*, *44*, 9-19.

Rivera-Batiz, Luis A. and Paul M. Romer (1991), "Economic Integration and Endogenous Growth," *Quarterly Journal of Economics*, *106*, 531-555.

Romer, Paul M. (1986), "Increasing Returns and Long Run Growth," *Journal of Political Economy*, *94*, 1002-38.

Romer, Paul M. (1993), "Idea Gaps and Knowledge Gaps in Economic Development," *Journal of Monetary Economics*, *32*, 543-573.

Samuelson, Paul A. (1948), "International Trade and the Equalisation of Factor Prices," *Economic Journal*, *58*, 163-84.

Solow, Robert M. (1956), "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics, 70*, Reprinted in Joseph E. Stiglitz and Hirofumi Uzawa (eds.), *Readings in the Modern Theory of Economic Growth*, Cambridge: MIT Press, 58-87.

Summers, Robert and Alan Heston (1995), "The Penn World Table (Mark 5.6)"

World Bank (1994), *World Tables*, CD-ROM.

Table 1: **Trade Group's Convergence Coefficients**

(sorted by output *t*-statistics)

	Export-Based Groups‡					
	Source Country	Size	Output Per Worker $\hat{\phi}$	Output Per Worker *t*-stat	Capital Per Worker $\hat{\phi}$	Capital Per Worker *t*-stat
1	NZ	5	0.956	-7.05 **	0.996	-0.92
2	CAN	3	0.945	-5.19 **	0.995	-1.01
3	AUSTL	4	0.945	-5.01 **	0.995	-0.96
4	GERM	9	0.963	-4.64 **	0.993	-1.80
5	US	6	0.966	-4.14 **	0.997	-0.97
6	IRE	7	0.975	-4.06 **	0.996	-1.35
7	JAP	3	0.977	-4.01 **	0.985	-4.95 **
8	FRA	8	0.964	-3.99 **	0.995	-1.22
9	AUSTR	6	0.965	-3.86 **	0.993	-1.47
10	UK	8	0.975	-3.85 **	0.993	-1.98 *
11	ICE	5	0.967	-3.72 **	0.996	-1.02
12	ITAL	6	0.966	-3.53 **	0.994	-1.23
13	SWIS	6	0.966	-3.53 **	0.994	-1.23
14	BELLU	7	0.968	-3.48 **	0.995	-1.14
15	NETH	7	0.968	-3.48 **	0.995	-1.14
16	MEX	4	0.966	-3.29 **	0.995	-1.08
17	SPA	7	0.973	-3.19 **	0.991	-2.15 *
18	SWED	9	0.975	-3.07 **	0.998	-0.59
19	FIN	7	0.973	-2.90 **	0.999	-0.21
20	NOR	7	0.976	-2.56 **	0.998	-0.61
21	DEN	7	0.978	-2.29 *	0.999	-0.41
22	ARGN	5	0.986	-2.25 *	0.998	-0.74
23	CHIL	8	0.991	-1.53	1.000	-0.07
24	URUG	6	0.994	-0.91	1.003	0.92
25	SA	6	1.002	0.91	1.000	-0.03

	Import-Based Groups‡					
	Source Country	Size	Output Per Worker $\hat{\phi}$	Output Per Worker *t*-stat	Capital Per Worker $\hat{\phi}$	Capital Per Worker *t*-stat
1	GERM	8	0.966	-5.94 **	0.991	-1.90
2	UK	9	0.967	-5.74 **	0.991	-2.05 **
3	ICE	9	0.963	-5.41 **	0.996	-1.49
4	FIN	6	0.962	-5.35 **	0.997	-0.95
5	SWED	9	0.968	-5.22 **	0.996	-1.27
6	NOR	9	0.968	-5.22 **	0.996	-1.27
7	CAN	3	0.945	-5.19 **	0.995	-1.01
8	JAP	3	0.936	-5.15 **	0.993	-1.21
9	AUSTL	6	0.964	-5.10 **	0.996	-1.08
10	NZ	6	0.964	-5.10 **	0.996	-1.08
11	AUSTR	4	0.938	-4.77 **	0.926	-5.13 **
12	DEN	9	0.972	-4.48 **	0.996	-1.44
13	US	6	0.966	-4.14 **	0.997	-0.97
14	SWIS	8	0.964	-3.99 **	0.995	-1.22
15	MEX	3	0.959	-3.58 **	0.996	-0.88
16	FRA	7	0.968	-3.48 **	0.995	-1.14
17	ITAL	6	0.970	-3.25 **	0.994	-1.22
18	IRE	5	0.980	-2.70 **	0.994	-2.04 *
19	BELLU	6	0.976	-2.57 **	0.998	-0.54
20	NETH	6	0.976	-2.57 **	0.998	-0.54
21	SPA	7	0.978	-2.54 **	0.992	-2.01 *
22	SA	6	0.992	-1.63	0.997	-0.92
23	ARGN	8	0.997	-0.90	0.996	-1.23
24	URUG	5	0.994	-0.85	1.003	0.86
25	CHIL	6	1.006	0.67	1.000	0.04

‡ The list of countries in each group may be found in Appendix Table A1. A legend of the abbreviations is in Table A2.

** Significantly different from one at the 1% level.
* Significant different from one at the 5% level.

Table 2: **Convergence in Total Factor Productivities**

(sorted by α=0.4 t-statistics)

Export-Based Groups

	Source Country	Size	TFP (α=0.4) $\hat{\phi}$	TFP (α=0.4) t-stat	TFP (α=0.3) $\hat{\phi}$	TFP (α=0.3) t-stat
1	FIN	7	0.955	-3.16 **	0.943	-3.81 **
2	SWED	9	0.966	-3.04 **	0.957	-3.59 **
3	NZ	5	0.954	-2.92 **	0.936	-4.58 **
4	AUSTL	4	0.957	-2.66 **	0.939	-4.27 **
5	GERM	9	0.965	-2.64 **	0.945	-4.20 **
6	MEX	4	0.941	-2.56 *	0.941	-3.48 **
7	AUSTR	6	0.959	-2.47 *	0.939	-3.70 **
8	JAP	3	0.963	-2.41 *	0.971	-3.16 **
9	FRA	8	0.966	-2.39 *	0.941	-3.92 **
10	SWIS	6	0.963	-2.26 *	0.936	-3.72 **
11	ITAL	6	0.963	-2.26 *	0.936	-3.72 **
12	URUG	6	0.973	-2.26 *	0.978	-2.20 *
13	ARGN	5	0.974	-2.24 *	0.977	-2.46 *
14	DEN	7	0.967	-2.18 *	0.946	-3.07 **
15	ICE	5	0.960	-2.07 *	0.948	-3.41 **
16	NOR	7	0.975	-1.84	0.956	-2.80 **
17	CHIL	8	0.983	-1.60	0.985	-1.65
18	UK	8	0.979	-1.56	0.966	-3.01 **
19	SPA	7	0.974	-1.46	0.948	-3.08 **
20	BELLU	7	0.977	-1.35	0.945	-2.99 **
21	NETH	7	0.977	-1.35	0.945	-2.99 **
22	US	6	0.988	-1.09	0.973	-2.68 **
23	IRE	7	0.987	-0.99	0.973	-2.33 *
24	CAN	3	0.994	-0.61	0.981	-2.02 *
25	SA	6	1.007	1.59	1.006	1.65

Import-Based Groups

	Source Country	Size	TFP (α=0.4) $\hat{\phi}$	TFP (α=0.4) t-stat	TFP (α=0.3) $\hat{\phi}$	TFP (α=0.3) t-stat
1	AUSTL	6	0.924	-4.68 **	0.929	-4.89 **
2	FRA	7	0.907	-3.58 **	0.913	-4.74 **
3	NETH	6	0.964	-3.45 **	0.959	-4.38 **
4	IRE	5	0.964	-3.45 **	0.959	-4.38 **
5	AUSTR	4	0.959	-3.22 **	0.953	-4.29 **
6	SPA	7	0.970	-3.00 **	0.963	-4.18 **
7	BELLU	6	0.964	-2.85 **	0.954	-4.20 **
8	ICE	9	0.960	-2.78 **	0.945	-4.34 **
9	GERM	8	0.960	-2.78 **	0.945	-4.34 **
10	US	6	0.966	-2.39 *	0.941	-3.92 **
11	NZ	6	0.976	-2.33 *	0.966	-3.85 **
12	CAN	3	0.967	-2.15 *	0.954	-4.67 **
13	FIN	6	0.979	-1.96 *	0.963	-4.11 **
14	URUG	5	0.975	-1.95	0.978	-2.05 *
15	JAP	3	0.977	-1.35	0.945	-2.99 **
16	ITAL	6	0.972	-1.31	0.964	-1.98 *
17	DEN	9	0.976	-1.30	0.942	-3.00 **
18	NOR	9	0.982	-1.13	0.969	-2.32 *
19	SWED	9	0.988	-1.09	0.973	-2.68 **
20	UK	9	0.994	-0.61	0.981	-2.02 *
21	SA	6	0.997	-0.57	0.997	-0.71
22	CHIL	6	1.002	0.22	0.996	-0.52
23	SWIS	8	1.013	0.73	0.978	-0.98
24	MEX	3	1.013	0.73	0.978	-0.98
25	ARGN	8	1.010	0.93	1.009	0.91

** Significantly different from one at the 1% level.
* Significant different from one at the 5% level.

Table A1: **List of Countries in Trade Groups**

(legend in Table A2)

	Source Country	Countries in Group							
Export-Based Groups									
1	CAN	JAPAN	US						
2	NZ	AUSTL	JAPAN	UK	US				
3	AUSTL	JAPAN	NZ	US					
4	ICE	GER	JAPAN	UK	US				
5	GER	AUSTR	BELLU	FRA	ITAL	NETH	SWIS	UK	US
6	SPA	FRA	GER	ITAL	NETH	UK	US		
7	JAPAN	SKOR	US						
8	FRA	BELLU	GER	ITAL	NETH	SWIS	UK	US	
9	AUSTR	GER	ITAL	SWIS	UK	US			
10	SWIS	FRA	GER	ITAL	UK	US			
11	ITAL	FRA	GER	SWIS	UK	US			
12	BELLU	FRA	GER	ITAL	NETH	UK	US		
13	NETH	BELLU	FRA	GER	ITAL	UK	US		
14	US	CAN	GER	JAP	MEX	UK			
15	CHIL	AUSTR	BRAZ	GER	ITAL	JAPAN	UK	US	
16	UK	BELLU	FRA	GER	IRE	ITAL	NETH	US	
17	SWED	DEN	FIN	FRA	GER	NETH	NOR	UK	US
18	ARGN	BRAZ	JAPAN	NETH	US				
19	FIN	DEN	GER	NOR	SWED	UK	US		
20	IRE	BELLU	FRA	GER	NETH	UK	US		
21	MEX	JAPAN	SPA	US					
22	DEN	FRA	GER	NOR	SWED	UK	US		
23	NOR	FRA	GER	NETH	SWED	UK	US		
24	URUG	ARGN	BRAZ	GER	UK	US			
25	SAFR	CONG	ETHI	GHAN	JAPAN	UK	US		
Import-Based Groups									
1	CAN	JAPAN	US						
2	DEN	FRA	GER	JAPAN	NETH	NOR	SWED	UK	US
3	JAP	AUSTL	US						
4	FIN	GER	JAPAN	SWED	UK	US			
5	GER	BELLU	FRA	ITAL	JAPAN	NETH	UK	US	
6	NOR	DEN	FIN	FRA	GER	JAPAN	SWED	UK	US
7	SWED	DEN	FIN	FRA	GER	JAPAN	NOR	UK	US
8	NZ	AUSTL	GER	JAPAN	UK	US			
9	AUSTL	GER	JAPAN	NZ	UK	US			
10	UK	BELLU	FRA	GER	ITAL	JAPAN	NETH	NOR	US
11	ICE	DEN	GER	JAPAN	NETH	NOR	SWE	UK	US
12	AUSTR	GER	ITAL	SWIS					
13	SWIS	BELLU	FRA	GER	ITAL	NETH	UK	US	
14	FRA	BELLU	GER	ITAL	NETH	UK	US		
15	ITAL	FRA	GER	NETH	UK	US			
16	NETH	BELLU	FRA	GER	UK	US			
17	BELLU	FRA	GER	NETH	UK	US			
18	US	CAN	GER	JAPAN	MEX	UK			
19	SPA	FRA	GER	ITAL	MEX	UK	US		
20	IRE	FRA	GER	UK	US				
21	MEX	JAPAN	US						
22	URUG	ARGN	BRAZ	GER	US				
23	SAFR	FRA	GER	JAPAN	UK	US			
24	CHIL	BRAZ	GER	GUYA	JAPAN	US			
25	ARGN	BOLI	BRAZ	FRA	GER	ITAL	JAP	US	

TABLE A2: **Legend of Countries**

	Code	Country
1	ARGN	Argentina
2	AUSTL	Australia
3	AUSTR	Austria
4	BELLU	Belgium-Luxembourg
5	BOLI	Bolivia
6	BRAZ	Brazil
7	CAN	Canada
8	CHIL	Chile
9	DEN	Denmark
10	ETHI	Ethiopia
11	FIN	Finland
12	FRA	France
13	GER	Germany
14	GHAN	Ghana
15	GUYA	Guyana
16	ICE	Iceland
17	IRE	Ireland
18	ITAL	Italy
19	JAPAN	Japan
20	MEX	Mexico
21	NETH	Netherlands
22	NOR	Norway
23	NZ	New Zealand
24	SAFR	South Africa
25	SKOR	South Korea
26	SPA	Spain
27	SWED	Sweden
28	SWIS	Switzerland
29	UK	United Kingdom
30	URUG	Uruguay
31	US	United States

THE FOERDER INSTITUTE FOR ECONOMIC RESEARCH and THE SACKLER INSTITUTE FOR ECONOMIC STUDIES

The Eitan Berglas School of Economics
Tel–Aviv University

List of Recent Working Papers

7–95 (Foerder)	Pierfederico Asdrubali, Bent E. Sorensen & Oved Yosha	Channels of Interstate Risksharing: US 1963–1990
8–95 (Foerder)	Yoram Weiss	Growth and Labor Mobility
9–95 (Sackler)	Rebecca Henderson Adam B.Jaffe Manuel Trajtenberg	Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting 1965–1988
10–95 (Foerder)	Daniel M.G.Raff Manuel Trajtenberg	Quality–Adjusted Prices for the American Automobile Industry: 1906–1940
11–95 (Foerder)	Jean–Marie Viaene Itzhak Zilcha	Multiple Uncertainty, Forward–Futures Markets and International Trade
12–95 (Sackler)	M June Flanders	Plus Ca Change...Plus c'est (Presque) La Meme Chose – A Review of Barry Eichengreen's *Golden Fetters*
13–95 (Foerder)	Aba Schwartz	The Interrelation of the Time Series of Wage and Employment at the Firm Level, Common Features and Contrasts
14–95 (Foerder)	Elhanan Helpman	The Size of Regions
15–95 (Sackler)	Assaf Razin Efraim Sadka	Public Debt in Israel: Policy Lessons
16–95 (Foerder)	Ami Navon, Oz Shy & Jacques–Francois Thisse	Product Differentiation in the Presence of Snob and Bandwagon Effects
17–95 (Foerder)	Arthur Fishman	Imperfectly Informative Equilibria for Signalling Games
18–95 (Sackler)	Arthur Fishman	Search with Learning and Price Adjustment Dynamics

Copies of the working papers or a complete working paper list of the two Institutes can be obtained from: Mrs.Stella Padeh, The Foerder Institute for Economic Research, Tel–Aviv University, Tel–Aviv, 69978 Israel. Fax: 972–3–640–9908. e–mail: foerder@econ.tau.ac.il

19–95 (Foerder)	Arthur Fishman	A Theory of Price Inertia
20–95 (Foerder)	David M.Frankel	A Pecuniary Reason for Income Mixing
21–95 (Sackler)	Ran Spiegler	Coordination and Matchmakers
22–95 (Foerder)	David M. Frankel	A Simple Model of Creative Bargaining
23–95 (Foerder)	Ariel Rubinstein Amos Tversky and Dana Heller	Naive Strategies in Competitive Games
24–95 (Sackler)	Zvi Eckstein Kenneth I.Wolpin	Estimating the Effect of Labor Market Discrimination on Black–White Differences in Wage Offers Using a Search–Matching–Bargaining Model
25–95 (Foerder)	Michael Kahneman	A Model of Bargaining Between Delegates
26–95 (Foerder)	Roberto Serrano & Oved Yosha	Decentralized Information and the Walrasian Outcome: A Pairwise Meetings Market with Private Values
27–95 (Sackler)	S.Rao Aiyagari Toni Braun and Zvi Eckstein	Transaction Services, Inflation and Welfare
28–95 (Foerder)	Benjamin Bental Zvi Eckstein	A Neoclassical Interpretation of Inflation and Stabilization in Israel
29–95 (Foerder)	Eran Yashiv	The Determinants of Equilibrium Unemployment: Structural Estimation and Simulation of the Search and Matching Model
30–95 (Sackler)	Elhanan Helpman	Politics and Trade Policy
31–95 (Foerder)	Gene M.Grossman Elhanan Helpman	Rent Dissipation, Free Riding, and Trade Policy
32–95 (Foerder)	Chaim Fershtman Yoram Weiss	Social Rewards, Externalities and Stable Preferences
33–95 (Sackler)	Yoram Weiss Robert J.Willis	Match Quality, New Information and Marital Dissolution

34–95 (Foerder)	Yoram Weiss Menachem Gotlibovski	Immigration, Search and Loss of Skill
35–95 (Foerder)	Dan Ben–David	Trade and Convergence Among Countries
36–95 (Sackler)	Dan Ben–David David H.Papell	The Great Wars, the Great Crash and Steady State Growth: Some New Evidence About an Old Stylized Fact
37–95 (Foerder)	David Pines	Multiple Private Goods in Clubs and Local Public Good Economies: A Unified Approach
38–95 (Foerder)	Yishay Yafeh Oved Yosha	The Strategic Use of Relationship Banking
39–95 (Sackler)	Chaim Fershtman Neil Gandal	The Effect of the Arab Boycott on Israel: The Automobile Market
40–95 (Foerder)	Dan Ben–David	Convergence Clubs and Diverging Economies
41–95 (Foerder)	Dan Ben–David	Measuring Income Convergence: An Alternative Test
42–95 (Sackler)	Dan Ben–David and Alok K.Bohara	Trade Liberalization and Income Equalization: A Long–Run Perspective
43–95 (Foerder)	Dan Ben–David	Convergence Clubs and Subsistence Economies
44–95 (Foerder)	Elhanan Helpman Genne M.Grossman	Technological Determinants of Trade
45–95 (Sackler)	Chaim Fershtman Aart de Zeeuw	Tradeable Emission Permits in Oligopoly
1–96 (Foerder)	Eyal Sulganik Itzhak Zilcha	The Value of Information: The Case of Signal–Dependent Opportunity Sets
2–96 (Foerder)	Gene M.Grossman Elhanan Helpman	Intergenerational Redistribution with Short–Lived Governments
3–96 (Sackler)	Jacob Glazer Ariel Rubinstein	What Motives should Guide Referees? On the Design of Mechanisms to Elicit Opinions
4–96 (Foerder)	Dan Ben–David and Atiqur Rahman	Technological Convergence and International Trade