Athreye, Suma; Cantwell, John

Working Paper

Creating competition? Globalisation and the emergence of new technology producers

Open Discussion Papers in Economics, No. 52

Provided in Cooperation with:
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DISCUSSION PAPERS IN
ECONOMICS

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Suma Athreye and John Cantwell

October 2005

NUMBER 52

***Copies may be obtained from**:*
Economics Department
Faculty of Social Sciences
The Open University
Walton Hall Milton Keynes MK7 6AA
Telephone: 01908 654437
Email: Socsci-economics-support-list@open.ac.uk
Fax: 01908 654488

This series is registered under
ISSN 1753-2590 (Print)
ISSN 1753-2604 (Online)

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Creating Competition?

Globalisation and the emergence of new technology producers*

Suma Athreye, *Economics, Open University, UK+.*

John Cantwell, *Rutgers Business School, USA.*

October 2005

Abstract:

This paper studies the emergence of new countries as contributors to technology generation in the world economy and assesses the relationship between this and globalisation (through trade, inward FDI and international migration). It considers two measures of technology generation, viz. a country's share of licensing revenues and of foreign origin patenting in the US, thus covering different phases and aspects of technological catch-up across countries. The paper uses a novel index to track the influence of new countries as technology generators in these datasets and uses time series techniques to understand the causal relationship between globalisation and the emergence of new technology producers. Our findings suggest a role for increasing international direct investment as a factor causing the emergence of new countries with the higher level competitiveness associated with patenting, but not in the recent surge of new countries with the basic capabilities needed to become licensors in the world economy. However, an increase in the international spread of the subsidiary sources of the patenting activity of multinationals appears to follow periods when the world economy becomes less open to trade.

Keywords: Technology, Innovation, Patenting, Licensing, Globalisation

JEL Codes: O33, F23, O19, F43, O57

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* We are grateful to the Open University for a small grant, which helped to collate the data required for the paper. We thank Elena Stassiouk and Nevena Yakova for timely research assistance and Ron Smith for guidance. The usual disclaimer applies.

+ Corresponding author: s.s.athreye@open.ac.uk

Creating Competition?

Globalisation and the emergence of new technology producers

There is considerable debate on the issue of whether new countries in the developing world are catching-up in technological capabilities and if they can emerge as significant producers of technology. Case studies suggest that countries like Ireland, Israel and India have emerged as significant exporters of technologically sophisticated products and services. A significant proportion of multinational company R&D has moved to countries of developing Asia - estimates suggest that the share of US affiliate R&D in Canada, Japan and Europe relative to the world as a whole decreased from 94% in 1989 to 85% in 1999, while the share of developing Asia grew from less than 1% to over 7.7%.[1] Yet our knowledge remains limited of whether this transfer of R&D has been associated with greater technological generation from new countries to a significant extent.

However, we also live in times when the unprecedented globalisation of the last two decades is under threat. On the one hand, researchers concerned with the development of poor countries in Africa are campaigning for Developed Market Economies to open a larger part of their market. Larger developing countries such as India and Brazil have also intervened aggressively for a fair deal in trading during the Doha and Cancun rounds of the WTO negotiations. On the other hand, recent trends in the outsourcing of intellectual labour have given rise to the fear in Developed Market Economies that they stand to lose their comparative advantage in knowledge-intensive products as new countries emerge with the basic capabilities needed to provide some technology-based services. At least two recent works on international trade by eminent economists argue that these fears may be well founded. Gomroy and Baumol (2000) show that in a multi-country, multi-product

[1] US Department of Commerce as cited in Beausang (2004), Table 1.

setting where international trade is based mostly on created comparative advantages and economies of scale, the terms of trade consequences of productivity improvements among trading partners may be such that the classical argument that free trade benefits all countries is overturned. In a similar vein, Samuelson (2004) has argued that productivity growth in trading partners may sometimes ‘permanently harm’ the trading country.

These concerns about the possibilities and consequences of productivity growth in trading partners are also closely related to the discussion of technological catch-up of developing economies, especially in the context of North-South trade. Increases in productivity in developing economies often start with simple technology transfer type activities, facilitated by openness and then proceed through investments by firms in capability building (within economies of the South) to become distinctive niches that underlie the competitive advantages of these nations.

Our paper speaks to these audiences and their concerns. It provides a quantitative assessment of the periods when new countries emerged as technology producers (thus demonstrating technological catch-up), and assesses how different phases and dimensions of technological catch-up are related to globalisation. We distinguish between the earlier phases of technological catch-up that rely on the building of simpler capabilities, the outcome of which forms part of what is measured by cross-border licensing revenues, and the attainment of higher level technology based competitiveness, which can be captured by the inventive sources of patenting. The paper also pays attention to different dimensions of globalisation in the world economy - openness to trade, share of foreign direct investment (FDI), the use of international locations as sources for patenting by multinational corporations (MNCs), and the proportion of the world’s population that migrated between countries.

There are two reasons to expect that the relationship between technological catch-up and globalisation varies with whether countries are at earlier stages of development that require simpler capabilities, or have entered a more mature phase of development that relies on sophisticated capabilities. First, when building simpler capabilities smaller firms may play a more prominent independent entrepreneurial role, and there is less need for organisational complexity and interconnected network structures. Therefore, earlier technological catch-up relies less upon a system for sustained and continuous international knowledge exchanges and interdependencies (of the kind that are facilitated by trade and FDI), but depends more in the first instance upon indigenous learning efforts. Second, the recent rise in technology trade and the outsourcing of knowledge-related functions that has accompanied the fragmentation of value chains has created new opportunities for those with at least basic capabilities in what were formerly less well internationally interconnected locations, especially in developing countries. Some countries with basic capabilities may thus now be able to establish new niches for themselves in international knowledge creation that does not depend on an already prevailing system of trade and FDI.

Indeed, our empirical findings suggest a strong role for increasing inward direct investment in the world economy as a factor inducing the emergence of new countries as patentees (which usually does require international knowledge interdependencies), but only some ambiguous evidence that greater openness to international trade explains the recent surge of new countries as licensors in the world economy. We interpret the latter finding as suggestive of the important role played by exogenous factors such as the emergence of generic technologies that have facilitated the growth of technology trade often in intangibles as argued by Athreye (1998) and Arora et al (2001). However, patenting by MNCs from international sources (that is, from the innovative efforts of their subsidiaries abroad) is enhanced by a weakening of the possibilities for trade. This may be because when openness to trade declines, host countries rely to a greater extent on a local presence by the subsidiaries of foreign-owned MNCs to foster technology creation, as opposed to international business knowledge linkages that come through trade and subcontracting. However, when international knowledge linkages are created through FDI, it facilitates the consolidation of higher level capabilities locally, even though FDI is not usually the means by which lower level capabilities are initially built up in the earlier stages of development. Taken together, these findings are consistent with the view that multinationals require the presence of local capabilities and infrastucture before they invest (Lall, 2001), and that they tend in recent times to have followed knowledge-based asset-seeking strategies to reinforce their competitive strengths as argued by authors such as Cantwell (1995), Dunning (1996), Makino et al (2002), Pearce (1999) and Wesson (2005).

The remainder of the paper is organised as follows: A brief review of the literature on the emergence of new technology producing countries and regions in Section 1, is followed in Section 2 by an outline of the method employed in our study, including a description of the method used to track technological catch-up in the world economy. Section 3 describes our main results and Section 4 concludes.

1. Factors influencing the emergence of new technology producing regions

The influence of globalisation and human capital on the technological capacities of a country is widely acknowledged in the literature on technology and development. Yet globalisation has a dual dimension in the way that it influences the emergence of new technology producers that is not often addressed in this literature. The rates of growth of exports and imports in the global economy provide or close a demand opportunity for all countries - this may be especially important in poorer countries where low incomes may cause domestic markets to be small to start with. Periods of relatively greater openness are therefore also often periods where the world economy enjoys a boom in demand as a result of growth in incomes of trading countries. This growth of demand may contain new technological opportunities inasmuch as technological opportunity is dependent both upon the novelty of product demand and a large scale of operations. Globalisation in this first sense provides the preconditions for the generation of technology within developing countries and is one dimension that underlies what we study in this paper - namely, through the measure of the openness of the world economy to trade.

The second dimension of globalisation (and the more widely studied one) is the ability of countries to exploit such demand booms. Here supply-side factors such as levels of infrastructure, stocks of human capital and existing technological capacity condition the influence of openness. Whilst openness allows opportunities to import capital goods and technology-embodied products, human capital, and linkages to demanding users such as foreign-owned firms may well play an important role in the exploitation of the opportunities offered by openness, but the capacity to exploit these advantages may also vary with dynamic firm capabilities and the institutional infrastructure of the country.[2] This second dimension is thus quite distinct from the first dimension, but is reflected in the geographical dispersion by multinational companies of their subsidiary sources of technological knowledge creation.

An important factor emphasised in the literature on the emergence of technology producing regions is that such regions embody 'untraded' competencies (Storper 1997) which includes technology generating economic and social institutions. Other studies have also highlighted the role of human capital and training and the inertia associated with such labour in some regions. Thus, studies on the emergence of new science based regions such

[2] See for example the discussions of 'social capability' (Abramovitz 1991) and the importance of 'absorptive capacity' in realising the benefits of foreign investment. (Narula and Dunning, 2000).

as those by Bresnahan and Gambardella (2004), Arora and Gambardella (2005), Florida (2002) suggest that human capital variations have opened up the possibility for new regions and nations to occupy distinctive technological niches in a global market based upon their comparative advantage in access to skilled labour. Recent examples of technological catch-up such as those of Israel and Taiwan point to the important role of openness and human capital investment in creating distinctive comparative advantage positions for the countries often in global production chains (Ernst 2002, Ernst and Kim 2002).[3] Human capital improvements are also often intertwined with the ability to exploit inward foreign direct investment. Thus, openness on one hand provides opportunities for the export of goods and services from new regions but a certain lack of mobility of some key local supporting factors (such as skilled labour, or universities) in the face of a generally open environment may also attract foreign direct investment of a local technology promoting kind.

It is also argued that the emergence of general purpose technologies, such as IT and biotechnology have created conditions in which new technology markets have emerged (Athreye 1998, Arora, Gambardella and Fosfuri, 2001). Key parts of this argument relate to the role of technological convergence (facilitated by the emergence of generic technologies) in creating a large scale of market, the lowered costs of experimentation due to easier trial and error (for example through the widespread use of computer aided simulation) and the emergence of new languages that allow some hitherto tacit knowledge to be codified. The emergence of these new markets however represents a changing division of labour where newer nations have a chance to specialise narrowly and emerge as technology producers. Some work from the study of patent data seems to support this

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[3] These case studies also emphasise the large and coordinated investments by numerous agents in the economy required to achieve success in technological catch-up and the role of indigenous institutions in imparting unique advantages to nations. It is beyond the scope of the aggregated level of analysis of this paper to examine these aspects of technological catch-up, though we think such factors do affect the inter-country differences in catch-up.

conclusion. For example, Cantwell and Vertova (2004) find that the technological diversification of nations has declined in recent years and from this they conclude that newer countries have different opportunities for catch-up when compared to earlier periods because they can afford to catch-up through a much narrower specialisation.

Thus, in assessing the factors due to which new countries emerge as technology producers in the world economy, we need to take account of the openness of the world economy, the movement of inward direct investment and migration as well as the growth and variation of the stock of human capital. In addition, the technological developments in the fields of IT and biotechnology may exercise an independent influence because the development of these fields has opened up huge opportunities for niche technologies based on recombination which many new countries with sufficient human capital can exploit. While these technological developments are not directly measurable, their influence has been noted in several studies since the late 1980s on the growing importance of the knowledge-based economy.[4]

2. Data and Methodology employed

The interrelationship between trade, foreign direct investment, human capital and economic growth, implies the challenge in statistically testing some of the relationships at the country level lies in overcoming the biases introduced by endogeneity in the statistical models. Consequently, disentangling their influence on growth and then on technological catch-up is problematic. In this paper we construct an aggregated measure of technological catch-up that does not depend upon growth measures in a direct way. This allows us to bypass some of the endogeneity issues to do with technology and growth. However, the interrelatedness between processes of globalisation and technology generation remains an

[4] See for example, Foray and Lundvall (1996) and Antonelli (1998).

important issue. Thus technology generation may respond to the demand opportunities created by openness while international producers may flock to regions of technological advantage. We use time series techniques to address these issues of interrelatedness and to assess the direction of statistical causality. This comes at a cost however, since we also lose much of the variation across countries in the data which we could exploit. Thus, one implication of the methodology we employ is that we cannot say very much about individual cases of success or failure of economies to emerge as technology producers.

2.1 Data used in the analysis

2.1.1 Measuring technological catch-up

We use two measures to evaluate a country's contribution to the production of technology in the world economy. The first is a country's share of patents issued by the USPTO that are attributable to all non-US inventors, and the second is a country's share of licensing revenues in the world economy.

The USPTO database has advantages and disadvantages in the analysis of technological behaviour and these have been widely discussed in the literature using patent data.[5] For our purposes a major advantage is that it helps us track the presence across countries of advanced technology generating capabilities. However, the US patent share of countries is an underestimate of the overall technological capacity of countries, which includes more basic capabilities that are less likely to be associated with the kinds of knowledge creation that gives rise to patenting. It may also be biased towards areas of industry which are dominant in US imports. For these reasons, US patents provide an over-representation of innovation in advanced manufacturing and in areas for which the US market may be important, but they are a poor representation of innovation of a simpler kind, in services and of technology trade that does not involve the US (e.g. trade between

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[5] See e.g. Schmookler, 1950, 1966, Pavitt, 1985, 1988; Griliches, 1990; Archibugi, 1992.

two developing countries). Since the mid-1980s, knowledge intensive services have been increasing in importance for economic activity with several new countries becoming involved in technology trade in these fields (e.g. software exports from India). For this reason we also use the share of a country in international royalty and licensing revenues as a second measure of their technological generation capacity. This better reflects earlier stages of the development process and other aspects of innovations that have arisen in more recent industrial history (most notably, innovation in services).

While patents can be used to generate licensing revenues, licensing can also happen without the issuance of patents. Licensing is the more prevalent way of trading technology-based business services between firms. However, it should be noted that unlike US patents, licensing revenues are probably far more influenced by local institutional conditions, transfer pricing practices of multinationals, and bilateral trade ties – factors that we will lose sight of in the high level of aggregation of our data.

The emergence of new countries as technology producers should result in a greater dispersion of technology shares as measured by indices of concentration like the Herfindahl. We compute the Herfindahl index of concentration using the following definition

$$H_t = \Sigma S_{it}^2, \qquad (1)$$

where S_{it} is the technology share of the ith country at time t. We then exploit a particular decomposition of the Herfindahl index, which splits the change in overall concentration into a turbulence effect and a regression effect.[6]

$$\Delta H_t = \Sigma_i (\Delta S_{it})^2 + 2 \Sigma_i (S_{it-1} \Delta S_{it}) \qquad (2)$$

In equation (2), the first term of the RHS measures technology share turbulence (the concentration of the change in shares). Both positive and negative changes have the same

[6] For an application of this decomposition to study the evolution of market shares and concentration see Kambhampati and Kattuman (2003).

weight in this index and the larger the value of the turbulence the more changes there will have been in technology shares. By construction the turbulence measure is always positive.

The second term is however, the more interesting one for tracking technological catch-up by new countries. It measures the linear association between initial technology share and the change in that share, weighting large initial shares more than small ones. We call this the Inverse Regression Index (IRI), since negative values imply a regression of country shares towards the mean.[7]

Negative values of the inverse regression effect come about when countries that had initially larger technology shares are also those with negative values of ΔS_{it}, (i.e. when these countries lose technology shares). When technology producers with small initial shares have gained or lost patent shares these are given a smaller weight and the cross term will have a smaller positive value than if the same were to happen to large patentees.

As new countries begin to make small gains in technology shares and erode the shares of existing nations they cause lower positive values for the turbulence term and a negative value for the inverse regression index. When some already dominant existing countries are increasing their technology shares both terms will be positive and higher. In general, turbulence tends to be greatest when it is the largest countries that make significant gains and losses against one another, since at that end changes in shares tend to be higher in absolute terms.

We use the IRI term as the dependent variable in a time series analysis to capture the existence of technological catch-up. Thus, we compute two IRI measures-one based on patent shares of countries (IRIP) and the second based on licensing (revenue) shares of countries (IRIL) and use these as the variables in our analysis.

[7] This very similar to the Galtonian regressions used in Cantwell (1991), in which the variance of shares is analogously decomposed into a mobility effect (measured by one minus the correlation coefficient), and a regression effect (measured by one minus the slope coefficient on lagged shares).

2.1. 2 The globalisation variables

The data for the globalisation variables are drawn by aggregating the data over countries from well-known data sources and these are detailed in the Appendix to this paper. We use four measures of globalisation in the world economy:

(i) Openness to trade as measured by the ratio of exports and imports to total world income (OPEN);

(ii) The ratio of inward FDI stock to gross world income (IFDI);

(iii) The share of patents that are assigned to the largest foreign-owned MNCs active in each host country across the world economy - a measure of the globalisation of R&D or patenting by MNCs from international R&D sources (INTPAT);

(iv) The proportion of population that migrated across countries as a percentage of the world population (PROPMIG).

We also looked at the possibility of including measures of human capital such as the share of tertiary educated population in the world economy, and the variance in the share of tertiary educated population in the world economy. However the earliest period for which such data became available in a consistent fashion was from 1970 and the data were available only for five yearly intervals. Given the relatively short span (for a time series analysis) we decided not to include these variables but to use an econometric methodology capable of controlling for the influence of such omitted factors.

Table 1 below describes the variables used in the study and their expected influence on IRIP and IRIL, based on the review of the previous section. We further note that since IRIP and IRIL may also be capable of influencing one another the direction of their relationship is potentially complex. The relationship may be expected to be positive for two reasons. First, patents are sometimes issued with a view to earning licensing revenues, so new patentees should also imply new licensees. Second, new licensors may over time acquire the higher grade capabilities and networks that permit them to become patentees, although the lag here from one to the other may be considerable. However, new technology producers may first test the market for their technologies through licensing, and especially when tacit elements of knowledge are important they may bundle licensing revenues with services. Once the scope for their market becomes clear, they may seek to patent their proprietary technologies. In this case new patentees will further concentrate licensing revenues and the relationship between IRIL and IRIP may become negative.

[Table 1 here]

Augmented Dicky Fuller tests (with a trend and intercept) were used to determine whether a variable was stationary or trended. The order of integration of all the explanatory variables, reported in Table 2, indicate non-stationary in all the globalisation variables. Since the IRI is constructed by decomposing the difference of the Herfindahl index for patents and licensing shares, it is stationary to start with. We thus used first differences of the globalisation variables along with IRIL and IRIP (in levels) for our estimation.

[Table 2 here]

[Figure 1 here]

Figure 1 plots the main trends in the explanatory variables we considered, while Table 3 reports the correlation matrix of explanatory variables. Figure 1 shows a rising trend in all the explanatory variables though the levels of OPEN, IFDI and INTPAT seem considerably higher than the values for PROPMIG. The correlation matrix also shows that the globalisation variables are very highly correlated in levels. De-trending the data by differencing we find the correlations are still evident but much more manageable for estimation purposes.

[Table 3 here]

2.2 Econometric methodology

We use a Vector autoregressive system of equations (VAR henceforth) to model the inter-relationship between the emergence of new technology producers and globalisation in the world economy. The estimated VAR takes the form:

$y_t = \alpha + A_1 y_{t-1} + \ldots A_p y_{t-p} + \varepsilon_t$

where y_t is a k vector of endogenous variables, α is a **k**-vector of constants, A_1-A_p are matrices of coefficients to be estimated and ε_t is an error term which we assume does not display any correlation with its own values or the right hand side variables. Thus each variable in the system is explained by its own past values and the past values of the other variables. For the **k** variables in the VAR system this gives us **k** separate equations to estimate simultaneously. In our case, **k**=6, viz. the four globalisation variables detailed in Table 1 and the two catch-up variables IRIP and IRIL.

VAR systems avoid many common problems such as simultaneity (only lagged values appear) and the absence of a full variable set (since we use lagged values of the dependent variable itself as an explanatory variable). However, they are intensive in their need for a long span of data at regular intervals. The lag length we use is also a matter of choice. We use statistical tests on the goodness of fit of the equations in order to choose the appropriate lag length.

To assess causality between the dependent and explanatory variables we used Granger causality tests. In this exercise we ask the data to predict observed values of the one variable (e.g. IRI) using past lagged values of the others (e.g OPEN). If the fitted model successfully predicts values of the dependent variable then we infer that OPEN granger causes the change in the IRI. This is in fact equivalent to rejecting the null hypothesis that coefficients of the lagged variable OPEN are all zero. We can also evaluate if all the globalisation variables are jointly significant in predicting changes in IRI. The first is an individual variable test of causality that evaluates the individual coefficients while the second is a joint test of the significance of all the coefficients. Both hypotheses are evaluated by the use of a χ^2 (Wald) test statistic. However, as this explanation makes clear, Granger causality tests have a strict statistical meaning, viz. that of causality as implying observational precedence, which may not always be the same thing as economic causality.[8]

3. Empirical analysis

3.1: Assessing periods of technological catch-up

Trends in patenting and licensing revenues suggest that both rose dramatically in the late 1980s and through the 1990s (see Figures A1 and A2 of the Appendix). The number of countries actively patenting in the dataset rose slowly from 42 in 1950 to a high of 60 in 1989, although not every country patented every year.[9] Similarly as Figure 2 shows the number of countries earning licensing revenues grew far more dramatically from about 35 in 1985 to over 83 in 2003. This is of course still a lot fewer than the total number of countries we were able to collect economic data for from sources like the Penn Tables and the World Development Indicators. Thus, like with firms, only a certain proportion of countries patent and license their technologies - thus demonstrating higher grade technological capabilities.

[Figure 2 here]

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[8] A popular classroom example of this is that it can be shown that weather forecasts granger cause the weather!

[9] These numbers exclude the US as a country of invention, which is (of course) the major patentee in the USPTO dataset. Thus, the patent share of the US alone was over 90% in 1950 and fell over time, but was still high at 55% in 1995. To get a clearer picture about the role of new countries in patenting, we consider all foreign invented patents issued by the USPTO – i.e. we exclude US invented patents. See the Appendix for details about the patenting data used in the study.

Figure 3 below shows the overall trend in the Herfindahl index for patents and for license shares. After a long period between 1954-1975 when overall concentration hovered around 15%, the index rose in the period between 1975-1992, reaching a value of 28 % in 1992 but then it fell again to levels close to 22%. Licensing revenues show a sharper decrease in overall inequality as the dramatic increase in countries reporting positive revenues in Figure 2 also suggests. Though the trend in licensing revenues appears to show a secular decline since the mid-1980s - the apparent break in trend in 1970 may reflect the different coverage of the pre-1970 data sources. The licensing data strongly suggest that more countries started to participate in generating technology and perhaps trading technological knowledge through licensing since the mid-1980s.

[Figure 3 here]

However, it is the shares of technology generation that went to these newer countries that are important – were they large enough to make a dent on the shares of the technological leaders? Figure 4 below plots the IRI term of equation (3) for both licensing shares and patent shares. Since patent numbers vary widely year-on-year they can cause individual patent shares to fluctuate widely. The variations in licensing revenues are even wider. To smooth the data for these variations we also plot a three period moving average for the two IRI terms.

[Figure 4 here]

Figure 4 shows that through much of the 1950s and 1960s the inverse regression index values for patents were negative, reflecting a loss of patent shares to new patentees. The negative values were somewhat larger in the 1950s than in the 1960s, when they hovered between 0.0 and 0.5. The period 1992- 2001 has also been one of catch-up, with smaller patentees gaining patent share. In the intervening period (1972-92) the index turned positive and continued to rise in value up until the mid-1980s. Thus, for much of the period since the mid-1970s a small number of countries consolidated their technological positions and accounted for a growing share of world technology generating capacity. This view of the overall concentration in technological activity in a few countries from 1975-92 is consistent with the results of another recent study, using a different methodology by Kumar and Russell (2002).

The values of IRI on licensing shares for the pre-1970 period are difficult to interpret as they may reflect the different source of data. However, from 1955-2003, the IRI for licensing was negative in 32 time periods and positive in only 17. This is comparable to similar values for the IRI in patenting: from 1950-2001 the IRI was positive in 12 time periods and negative in 38. In the case of licensing revenues too, there seems to have been some consolidation in the late seventies and early eighties but mostly, negative values thereafter. Indeed unlike the case of patenting, the decline in IRI for licensing sets in much earlier in the mid-1980s and stays negative for much of the remaining period.

In both cases, there was relatively little turbulence in the cross-country distribution, and so the changes in the Herfindahl index were mostly due to changes in the Inverse Regression Index. As we explained in Section 2.1 this is an indication that new countries have emerged as significant technology producers.

3.2 Results of the VAR estimation

Tables 4 reports the results of the VAR estimations described in Section 2.3. The results are reported in matrix form with column headings indicating the equation being reported. The t-values of coefficients appear in square brackets under the coefficient values- values greater than 1.56 indicate significance at the 5% level. The Likelihood Ratio test, the Akaike Information Criterion and the Final Prediction Error tests (not reported in the paper) showed a lag length of one period to be the appropriate one to use in our estimation.[10] To take account for the different source of the data from 1970 and the apparent break in trend caused by it, we substituted the average of values from 1969 to 1971 for the year 1970.

Looking at the results of the first VAR equation (for IRIP), we find that the IRIP is affected by its own lagged values. IFDI has a negative, statistically significant coefficient. Since negative values of the IRIP indicate the emergence of new patentees we conclude that increases in IFDI is associated with the emergence of new technology producers with higher level capabilities. INTPAT and PROPMIG also influence IRIP, but positively, and so increases in MNC patenting from international sources and the proportion of migrant population are associated with concentrating technology production among existing patentees. IRIL does not have a significant impact on IRIP.

Moving to the next column, we find that IRIL is not influenced by its own past values or even IRIP. However, as might be expected, it is negatively associated with OPEN, and thus greater openness to international trade helps to promote the emergence of new technology producers that have the basic capabilities needed to become licensors. OPEN is itself associated with higher IFDI and lower MNC patenting from international sources. IFDI is influenced by its own past values, whilst PROPMIG is influenced by both OPEN and IFDI. INTPAT is negatively associated with OPEN.

Some of these results accord with what is observed in other cross-country studies. Studies of the Four Dragons and Japan for example, show the role of openness and foreign-owned firms in technology acquisition and the technological capability building process (Hobday, 1995). The results on licensing suggest that with basic capabilities openness to trade is more important than the attraction of FDI. In the earlier stages of development international business linkages can take a variety of forms (such as the export of

[10] All tests were evaluated at the 5% level of significance. The Schwarz Information Criteria and the Hannan-Quinn Information criteria indicate a lag length of zero is appropriate.

components to MNC networks under subcontracting agreements). This is also consistent with the view that the opportunities offered by the growth of technology trade have opened up a new potential amongst certain countries to take advantage of some established capabilities through knowledge service provision that need not be tied to FDI networks. Put differently, the growing division of innovative labour between countries may be based as much upon a widening of the kinds of comparative advantage of nations that are relevant to knowledge provision, as it is upon the availability of new technological opportunities as such. Secondly, as we noted earlier licensing is more sensitive to local institutional and governance factors. These factors would exercise less influence on patenting through the USPTO. The aggregated measures for the world economy effects that we use in this analysis would not be able pick up individual country level processes.

3.3. Assessing Granger Causality

We turn now to the Granger causality tests that reported in Table 5. Wald statistics are shown against each variable along the columns. The results for IRIP show that IFDI, INTPAT and PROPMIG *granger causes* changes in the IRIP. Further, we cannot reject the hypothesis that the influence of the globalisation variables jointly is equal to zero, i.e. they are *jointly relevant* to predicting the emergence of new patentees. In contrast, IRIL is not influenced individually or jointly by any of the globalisation variables.

Turning now to the globalisation variables we find INTPAT *granger causes* OPEN, and OPEN *granger causes* INTPAT. There is thus, bi-directional causality between these two variables. However, FDI is not influenced by the values of any of the other variables. PROPMIG is influenced by all the other globalisation variables. There is no suggestion however, that the globalisation variables are themselves caused by changes in IRIL and IRIP.

As we noted earlier, Granger causality interprets causality in a narrow way as a matter of statistical precedence. Yet we feel our results may be consistent with an interpretation of economic causality because both of our main findings with respect to IRIP and INTPAT are consistent with the observation made by many scholars that inward FDI seeks global sources of competitive advantage and will be drawn to regions of advantage. Further, though periods of globalisation in the world economy have also always thrown up new technology producers in the world economy – this has often been relatively few new countries.

4. Summary and conclusions

In this paper we use measures of technological catch-up in the world economy to try and assess periods of catch-up as well as to assess to what extent globalisation causes changes in catch-up. These trends differ depending upon whether we look at the geographical dispersal of the more sophisticated capabilities associated with patent shares or the wider range of capabilities reflected by licensing (revenue) shares. Patenting shows evidence of technological catch-up in the 1950s and 1960s and again in the period 1992-2001. However, licensing revenues show a secular trend towards the emergence of new countries as licensors starting from the mid-1980s onwards and gathering speed in the 1990s. This trend we speculate may be related to the new opportunities for niche strategies connected with the increasing importance of knowledge-intensive services since the 1980s, noted by several scholars.

Studying the impact of globalisation in explaining the emergence of new producers of technology we again find dissimilar results for patenting and licensing (revenue) shares. In the case of patenting we find evidence that inward foreign direct investment matters in the emergence of new technology producers with the higher level capabilities needed.

MNC patenting from international sources and international migration also matter - they promote concentration of patent shares, and thus constrain the incidence of higher levels of technological catch-up across countries. Looking at licensing shares however, the influence that runs from greater openness in the world economy to the emergence of new countries as licensees does not appear to be robust, as it holds only in our VAR analysis and not in the tests of Granger causality.

Lastly, despite the weakness of the effect of changes in the openness of the world economy on the emergence of lower level new technology producers, we do find that openness influences the other variables of globalisation. More open periods are also periods of higher migration. Further, a reduction in openness in the world economy predicts an increase in the extent of MNC patenting from international sources, and perhaps from new locations. Both of these trends however imply the consolidation of technological knowledge creation in fewer countries, albeit by means of drawing upon resources from outside the established home bases of MNCs.

Our results are also suggestive of a general pattern in the linkages between globalisation and technological catch-up that may not be true of all countries at all times, but which has been observed on average in the post-war period. That is, in the earlier stages of capability development, catch-up relies mainly on a localised and indigenous learning that is not closely interconnected with current knowledge creation elsewhere in the world, and so does not rely on prior FDI. However, once basic capabilities are formed, locations can begin to act as creative nodes within global production networks, initially more commonly through trade and subcontracting linkages, rather than through FDI. Yet when the scope of trade and subcontracting networks are reduced, the role of local subsidiaries in knowledge-creating nodes is likely to be increased. That is, the wider dispersion of knowledge-generating capabilities by multinational firms come to take advantage of new potential sources of ideas and begins to integrate them more fully into their international corporate networks. Indeed, when moving on to the higher levels of technological development needed for the later stages of catch-up, participation in the international interconnectedness of knowledge networks provided by MNCs through FDI are more likely to be a precondition.

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FIGURES

Figure 1: Trends in the globalisation variables

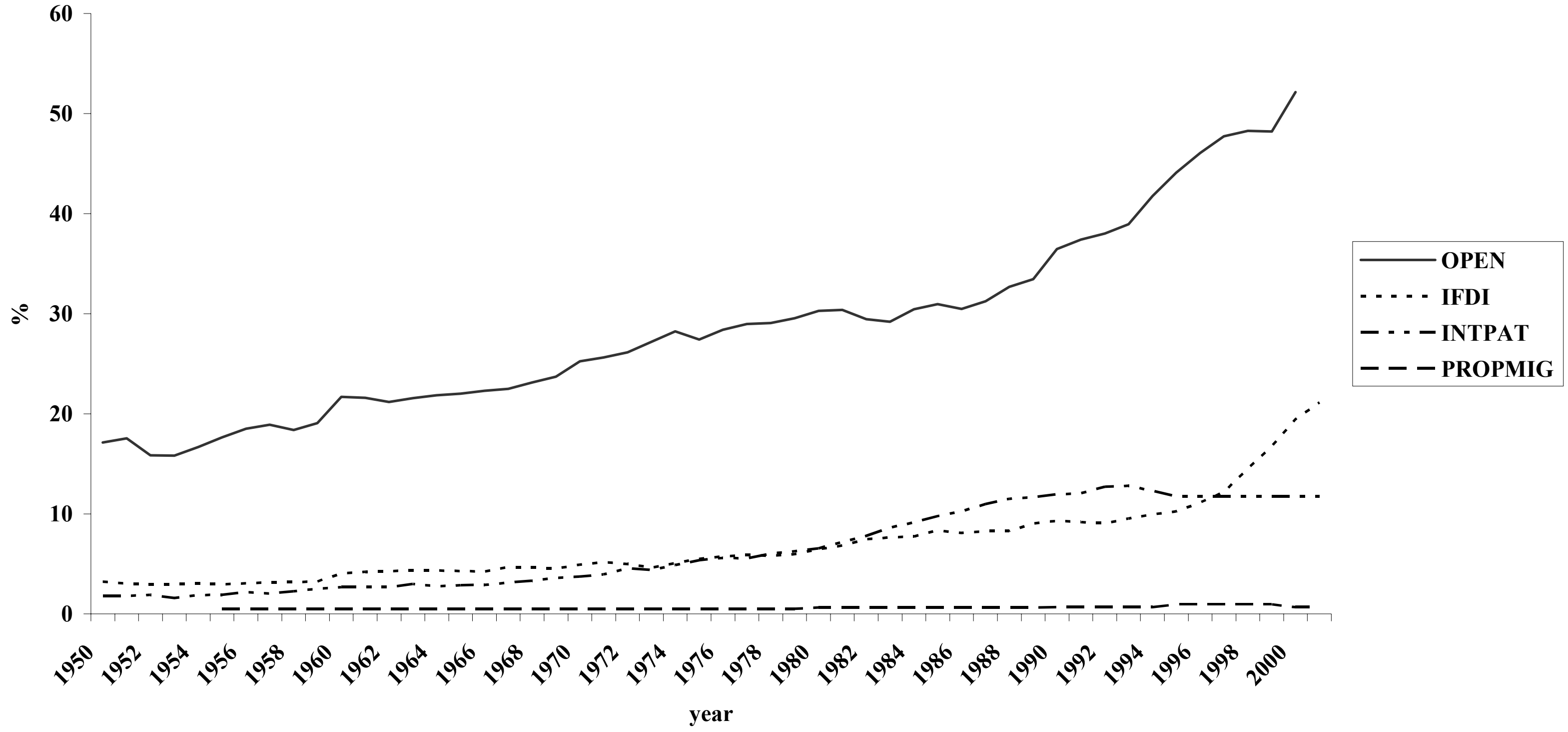


Figure 2: Patents and Receipts of Royalty and Licensing fees (1950-2003)
number of reporting countries by year

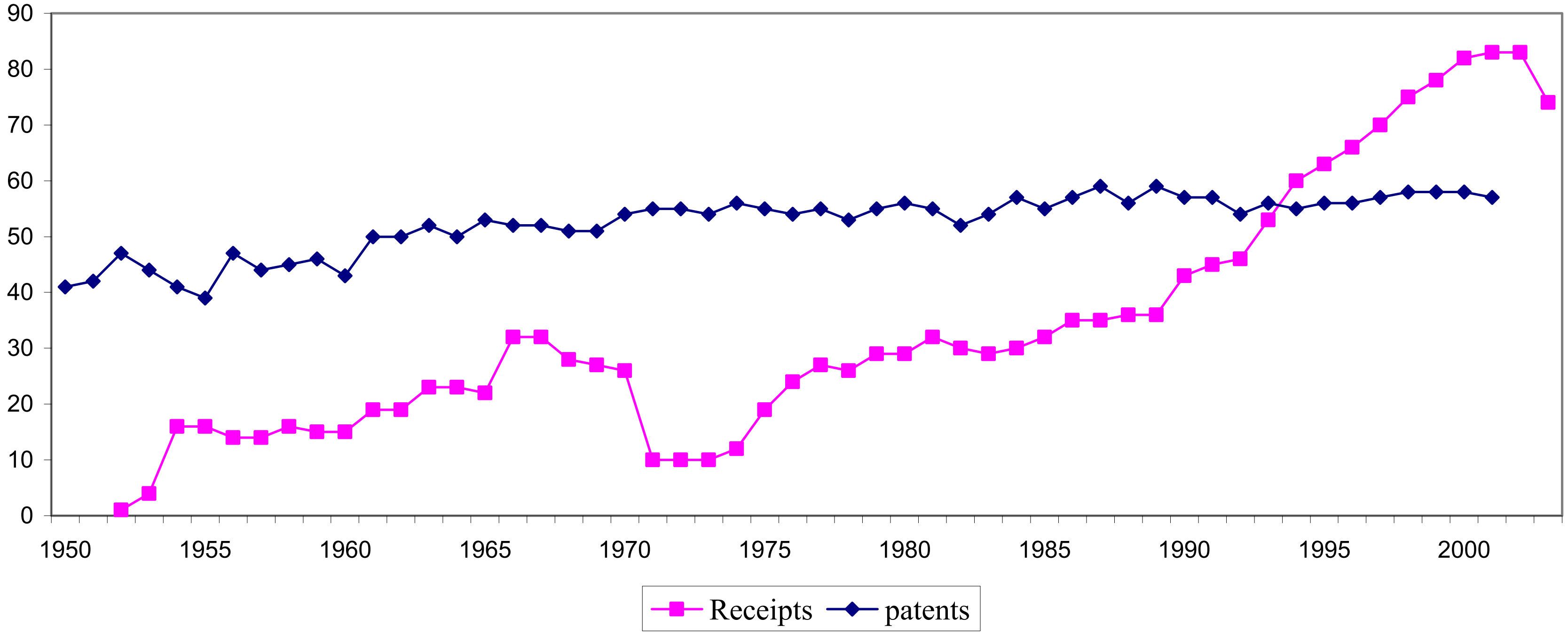
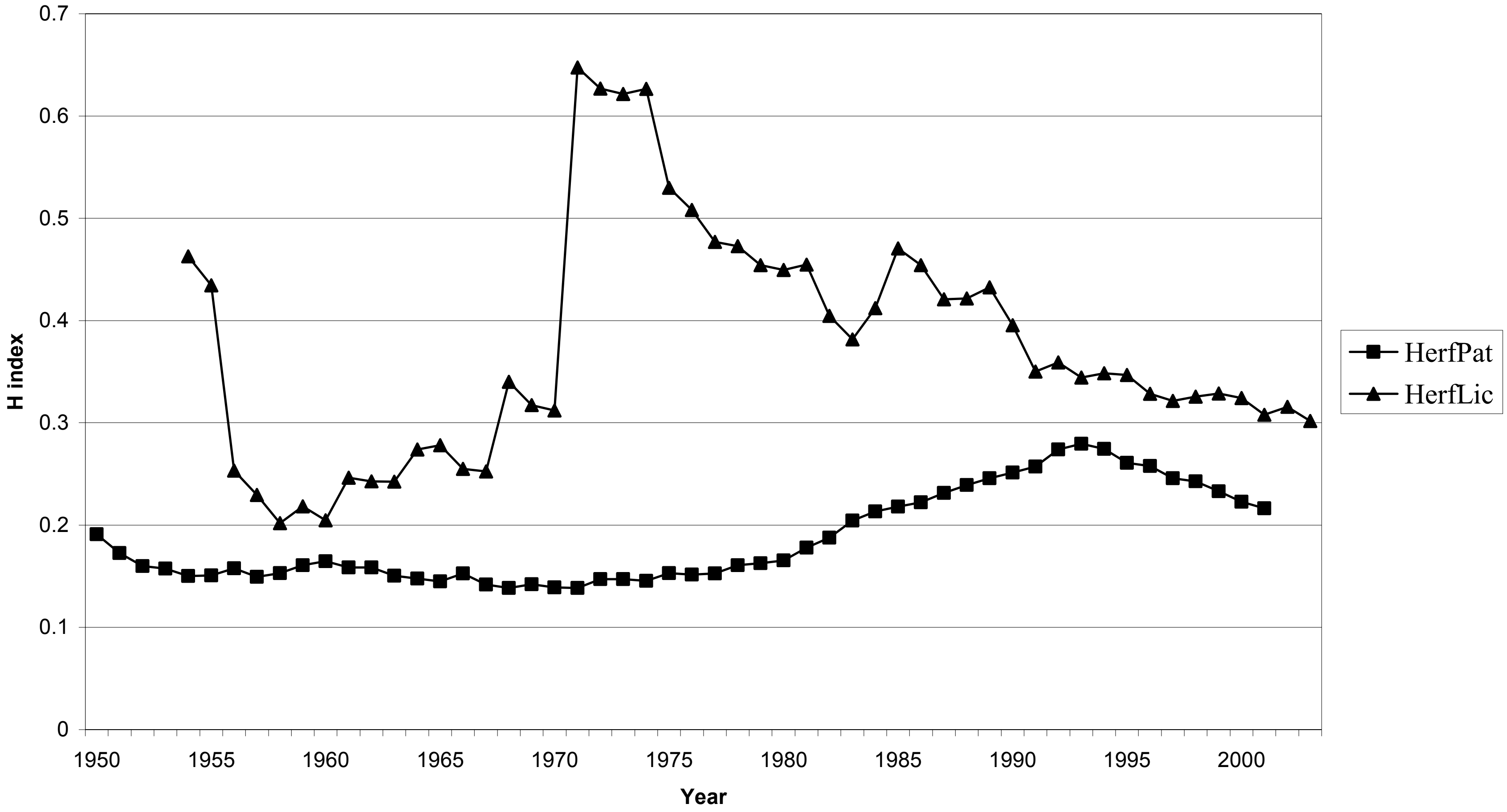


Figure 3: Herfindahl index of Patents and Licensing revenues



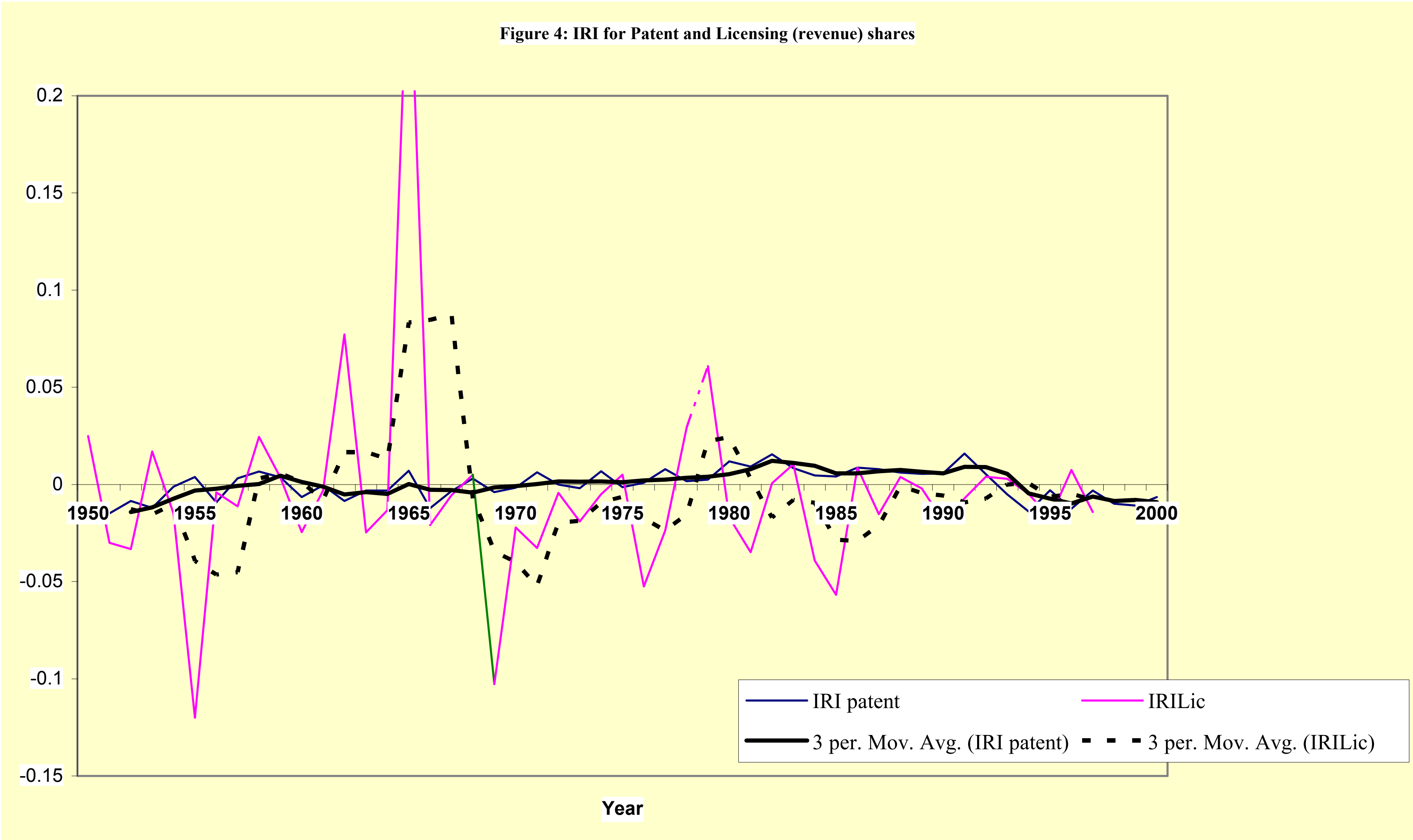


Figure 4: IRI for Patent and Licensing (revenue) shares
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year
IRI patent
IRILic
3 per. Mov. Avg. (IRI patent)
3 per. Mov. Avg. (IRILic)

TABLES

Table 1: Explanatory Variables used in the econometric analysis (All ratios expressed in percentages)

Variable	Description	Influence on IRIP/IRIL
OPEN	(Import + Export) / real GDP (1996 constant)	-
IFDI	Share of Inward FDI Stock as a proportion of World GDP	-
INTPAT	Share of patents assigned to large foreign-owned firms in foreign locations	+
PROPMIG	Absolute value of migrant population to world population	?

See Appendix for data sources used in the construction of the variables.

Table 2: Results of ADF Unit Root Tests

Variable	Order of Integration	Data Span
IRIP	I(0)	1950-2001
IRIL	I(0)	1955-2001
OPEN	I(1)	1950-2000
IFDI	I(2)	1950-2000
INTPAT	I(1)	1950-2001
PROPMIG	I(1)	1955-2000

Note: All tests are significant at the 5% level of significance

Table 3: Cross correlation matrix of explanatory variables (in levels and differences)

Levels

	OPEN	IFDI	INTPAT	PROPMIG
OPEN	1.00			
IFDI	0.93	1.00		
INTPAT	0.81	0.93	1.00	
PROPMIG	0.89	0.89	0.72	1.00

Differences

	OPEN	IFDI	INTPAT	PROPMIG
OPEN	1.00			
IFDI	0.17	1.00		
INTPAT	-0.63	-0.17	1.00	
PROPMIG	0.30	0.08	-0.45	1.00

Table 4: VAR estimation (1955-2001), t-values in square brackets

	$IRIP_t$	$IRIL_t$	$\Delta(OPEN)_t$	$\Delta(IFDI)_t$	$\Delta(INTPAT)_t$	$\Delta(PROPMIG)_t$
Constant	0.00	0.00	**0.01**	0.19	**0.22**	0.02
	[-0.41]	[0.05]	**[2.61]**	[1.37]	**[2.65]**	[0.85]
$IRIP_{t-1}$	0.04	-0.80	0.49	5.96	5.86	2.12
	[0.20]	[-0.74]	[1.54]	[0.42]	[0.68]	[1.08]
$IRIL_{t-1}$	-0.02	0.06	0.02	1.58	0.28	-0.07
	[-0.68]	[0.40]	[0.36]	[0.75]	[0.22]	[-0.23]
$\Delta(OPEN)_{t-1}$	-0.09	**-1.08**	0.07	-1.07	**-11.10**	**2.54**
	[-0.75]	**[-1.62]**	[0.37]	[-0.12]	**[-2.07]**	**[2.10]**
$\Delta(IFDI)_{t-1}$	**0.00**	-0.01	**0.00**	**0.89**	-0.04	**-0.05**
	[-1.92]	[-0.65]	**[1.56]**	**[6.56]**	[-0.49]	**[-2.49]**
$\Delta(INTPAT)_{t-1}$	**0.01**	0.00	**-0.01**	-0.35	0.30	-0.07
	[2.69]	[-0.16]	**[-1.68]**	[-1.02]	[1.43]	[-1.52]
$\Delta(PROPMIG)_{t-1}$	**0.04**	-0.01	0.01	0.40	1.38	-0.21
	[1.82]	[-0.13]	[0.25]	[0.27]	[1.54]	[-1.03]
Diagnostics (single equations)						
R-squared	0.43	0.10	0.15	0.59	0.32	0.31
Adj. R-squared	0.34	-0.05	0.02	0.52	0.21	0.20
Sum sq. resids	0.00	0.04	0.00	7.43	2.73	0.14
F-statistic	4.64	0.67	1.11	8.72	2.93	2.77
Log likelihood	166.35	90.28	143.77	-23.31	-1.25	64.08
Akaike AIC	-7.24	-3.79	-6.22	1.38	0.38	-2.59
Schwarz SC	-6.96	-3.50	-5.93	1.66	0.66	-2.31
Diagnostics (VAR system)						
Log likelihood		460.70				
Akaike information criterion		-19.03				
Schwarz criterion		-17.33				

Table 5: VAR Granger causality (Wald) tests

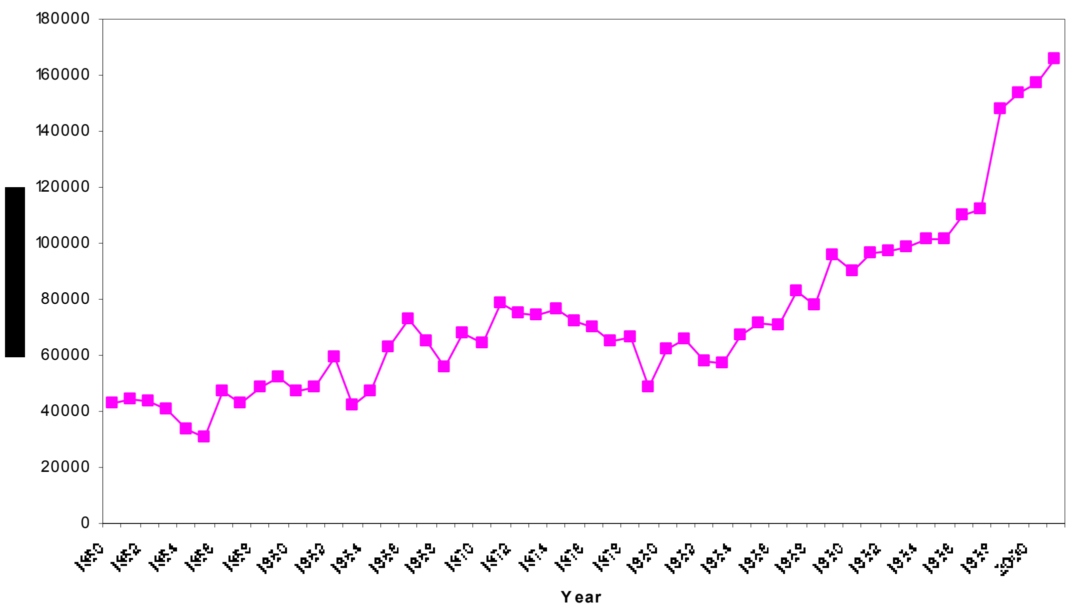
Dependent variable: IRIP				IRIL				Δ(OPEN)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
IRIL	0.46	1	0.50	IRIP	0.55	1	0.46	IRIP	2.37	1	0.12
Δ(OPEN)	0.56	1	0.45	Δ(OPEN)	2.62	1	0.11	IRIL	0.13	1	0.72
Δ(IFDI)	3.70	1	0.05	Δ(IFDI)	0.43	1	0.51	Δ(IFDI)	2.43	1	0.12
Δ(INTPAT)	7.23	1	0.01	Δ(INTPAT)	0.03	1	0.87	Δ(INTPAT)	2.84	1	0.09
Δ(PROPMIG)	3.32	1	0.07	Δ(PROPMIG)	0.02	1	0.90	Δ(PROPMIG)	0.06	1	0.80
All	15.12	5	0.01	All	4.02	5	0.55	All	5.06	5	0.41
Δ(IFDI)				Δ(INTPAT)				Δ(PROPMIG)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
IRIP	0.17	1	0.68	IRIP	0.46	1	0.50	IRIP	1.17	1	0.28
IRIL	0.56	1	0.45	IRIL	0.05	1	0.82	IRIL	0.06	1	0.81
Δ(OPEN)	0.02	1	0.90	Δ(OPEN)	4.29	1	0.04	Δ(OPEN)	4.40	1	0.04
Δ(INTPAT)	1.04	1	0.31	Δ(IFDI))	0.24	1	0.63	Δ(IFDI)	6.22	1	0.01
Δ(PROPMIG)	0.07	1	0.79	Δ(PROPMIG)	2.39	1	0.12	Δ(INTPAT)	2.30	1	0.13
All	2.19	5	0.82	All	6.37	5	0.27	All	16.59	5	0.01

Appendix: Data sources

We use two measures of the IRI index as the dependent variable: the first computed over patent shares and the second computed over shares of licensing revenues.

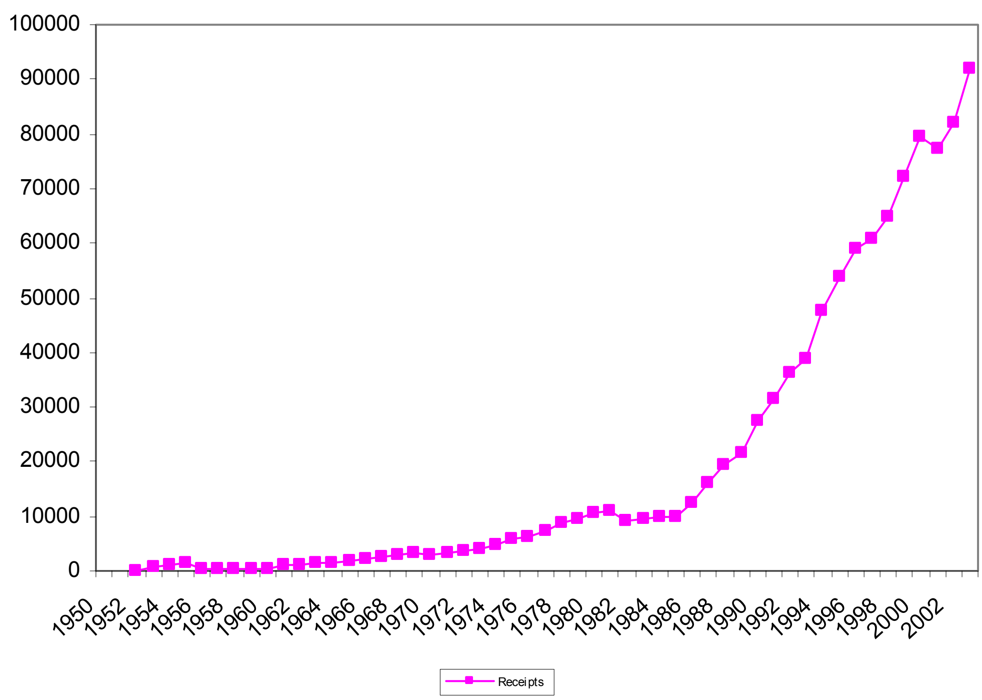
The *patent shares* we use are the share of each country in the patents issued every year by the USPTO that are attributable to all non-US inventors. The total number of patents in each year is shown in Figure A1 below.

Figure A1: Growth in non-US held Patents (1950-2001)



The *share of licensing revenues* was calculated by collating information from two sources. For the period 1950-70, we consulted The IMF Balance of Payments Yearbook (various years), which reports royalty and licensing fees in current USD by country. From 1970-2001, we used the World Development Indicators database that collates royalty and licensing revenues in current USD separately for each country (http://www.worldbank.org/data/onlinedatabases/onlinedatabases.html). Data for the total licensing revenues for the world economy for the period 1970-2003 were available from the World Development Indicators online database, and for the period 1950-1969 the values were calculated by summing up licensing revenues by each country for the period 1950-1969 - these are plotted in Figure A2 below. Country shares of world licensing revenues were then computed by dividing each country's revenue by the total for the world economy in any year.

Figure A2: Royalty and Licensing fees (1950-2003)
millions USD



The explanatory variables were collated from diverse sources. The *openness index* has been computed using data contained in the Penn World Tables (http://pwt.econ.upenn.edu/ - last downloaded March 2005).

Inward FDI stocks in current USD by country and aggregated for the world economy were available in a consistent way for the period 1980-2001, from the World Investment Report (2004) published by UNCTAD (http://www.unctad.org/Templates/Page.asp?intItemID=1890&lang=1). For earlier years (1950-79) we constructed the Inward FDI stock by extrapolating on the basis of available Inward FDI flow data for the same period and utilizing Inward FDI stock data for several benchmark years that were available. For the years 1950, 1960, 1967 and 1973 we used the data in Dunning (1993: Chapter 5), and for 1966 and 1971 the estimates reported in UNCTC (1973). MNCs in World Development. We estimated the end of year stocks in all the intervening years between benchmark years by proportioning the overall change in stocks between years in line with the proportioning of the total cumulative flow.

Inward FDI flow data for 1970-1979 are available from UNCTAD Handbook of Statistics (online database). Where Inward FDI flows were not available (1950-1964), World total Inward FDI flows were assumed equal to the sum of the US and UK outflows. Inward FDI flow data for the period 1965-1969 is provided by UNCTC(1973). Inward FDI stock data by country for the year 1975 was estimated in Dunning & Cantwell (1987).

The *proportion of international patents* was computed by identifying the patents held by large foreign-owned firms that were attributable to subsidiary sources of invention outside their respective home countries. We aggregated these data, available by host country and year (1950-1995), to create a measure of the number of foreign held patents in the world economy. For the period 1996-2001 we used the 1995 values.

International migration data were available by country for five year intervals from the UN Common database downloadable from (http://unstats.un.org/unsd/cdb/cdb_help/cdb_quick_start.asp). The figure for net migration refers to the net average annual number of migrants, that is, the annual number of immigrants less the annual number of emigrants, including both citizens and non-citizens. Migration as percentage of total population was calculated by utilizing population data from the World Population Prospects, published by UN Population division and available online at (http://esa.un.org/unpp/).

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