Technological Specialization in International Patenting

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Revised: January, 1998

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Abstract

Countries differ in their absolute and relative productivities in doing research across different technologies. They also differ in their propensity to adopt different technologies from abroad. Moreover, technologies may vary in their international mobility. We make use of new data on international patenting within different technologies to infer how countries specialize and which technologies are most mobile. We find countries to be much more specialized in their production than in their use of technologies, suggesting agglomeration effects in research. Innovations in chemistry and nucleonics are the most internationally mobile while those in agriculture and building are the least so.

1 Introduction

Explaining why poor countries are poor, and how poor countries become rich has been a central effort of our profession for over two centuries, and one to which Gus Ranis has made an enormous contribution. One polar explanation is that rich countries are rich simply because they have more capital and a better educated workforce. Another is that rich countries are rich because they operate with more advanced technologies.

Mankiw (1995) makes a vehement case that the first pole provides a good working hypothesis: Since people "can read blueprints anywhere," he finds the existence of serious impediments to technology flows implausible. In their classic book on the development of the labor surplus economy, Fei and Ranis (1964) are more skeptical about the ease with which poor countries can import foreign technology:

> While the availability of potentially useful techniques developed abroad certainly represents an asset in terms of the avoidance of costly trial and error, and while the advantage of a latecomer status should be exploited to the fullest, it is rarely economically sound or feasible that such techniques should be transplanted whole to the underdeveloped economy without considerable adjustment and adaptation to the radically different conditions prevailing. (Fei and Ranis, 1964, p. 66).

Ranis (1979) elaborates this point:

> It is not our view that there is some vast national and international shelf of technology ready to offer just the "right" process or product to

> be plunked down in a particular country and industry context. While the choice of a technology already in use elsewhere is a critical step—and by no means easy or costless, as we shall see—modifications will almost always have to be made before it can be installed and become fully "appropriate". (Ranis, 1979, p. 27)

How serious are impediments to technology flows? While, as Mankiw (1995) points out, we do not observe these flows directly, they do leave footprints. Our research is directed toward exploring a particular set of footprints, international patents.

Obtaining patent protection is costly. Many minor innovations are not patented at all, while many others are patented only where they are invented. A decision to patent an invention in a foreign country presumably reflects the inventor's expectation that it might prove useful, and hence have a market, there, justifying the cost of patenting.[1] Patent data should tell us something, then, about where inventions will be used, and how often they cross international borders.

Previous studies, including Slama (1981), Bosworth (1984), and Evenson (1984), have exploited the international patenting data for this purpose. Evenson (1984) found that the vast majority of patents originate from inventors in a few industrialized countries and that nearly all the patenting in developing countries is done by foreigners. This pattern suggests an underlying diffusion process from the more to the less advanced economies.[2]

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[1] A patent right excuses others from making, using, or selling the patented device. Thus, patenting abroad also forecloses manufacturing for export to third markets.

[2] This interpretation is also consistent with the concentration of the world's R&D activity in a few industrialized countries and with the direction of high-technology trade.

Eaton and Kortum (1996, 1997) use aggregate data on international patenting to infer patterns of technology diffusion among industrialized countries. Their estimates imply that research performed abroad is about two-thirds as potent as domestic research for these countries. Putnam (1996) uses micro-level data on the set of countries where inventors sought patent protection for a particular invention to estimate a model of the patent-filing decision. He estimates that over 95 per cent of the total value of patent rights worldwide is contained in inventions that are filed in at least one country outside their home country.

These studies have focussed on the geographic dimensions of invention and patenting, but have ignored the technological dimension.[3] Yet the technological dimension of the patent data is one of its unique and perhaps most interesting features. This dimension arises because patent examiners assign patents to internationally-consistent classes of technology defined by the International Patent Classification (IPC) system. In this paper we explore the interaction between the technological and geographical dimensions of the patent data. We examine differences across technologies in terms of where innovations occur, where they are used, and their rate of migration abroad.

In the present study, we extend the aggregate framework of Eaton and Kortum (1996) to allow for differences across classes of patented technology. The

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[3] Putnam (1996) does estimate separate models for pharmaceutical inventions and for all inventions. He finds much higher patent values, on average, for pharmaceuticals, but does not separately estimate the fraction of total value attributable to international inventions. The study closest to ours is by Archibugi and Pianta (1992) who examine the distribution over technologies of patents received by the European Patent Office and by the U.S. Patent Office. The work of Cantwell (1989) is also related although he uses U.S. patent data by industry and does not consider the technology classes themselves.

Eaton-Kortum model yields a decomposition of the multi-dimensional international patenting data that illuminates a number of issues about technological mobility: In particular, it allows us to examine: (1) which countries are the major sources and destinations of innovation in the world economy; (2) which country pairs tend to share their inventions the most; (3) to what extent do countries specialize as sources and destinations for specific classes of technology; and (4) which technologies appear to be most mobile?[4]

Answers to these questions shed light on a number of policy issues. For developing countries an issue of particular interest is the appropriate direction of research and development effort. Our analysis helps to identify (1) the technologies for which research performed abroad is most likely to prove transferable; (2) the countries which provide those technologies; and (3) the technologies for which domestic research is most needed to obtain productivity advances. For example, we provide further evidence that, for a small country, at least, the national payoff to research in agriculture might be particularly high, since innovations in this area appear least able to cross international borders.[5]

By applying some theory, we can infer the size of our quarry from the tracks

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[4] One limitation of our data is that, while we have the technological detail, we do not have patent data for developing countries. This limits us somewhat in the answers that we provide to these questions, particularly as they relate to economic development. The data do include, however, patents applied for by inventors from all over the world. As we discuss below, most patent activity occurs in developed countries.

[5] See Huffman and Evenson (1993) for a comprehensive survey of the returns to national and international agricultural research and extension expenditures. Dowrick and Gemmell (1991) provide very different evidence that bears on this issue. Using aggregate data they find evidence of technological catch-up in manufacturing, but not in agriculture.

that it leaves. Section 2 of the paper provides a model of innovation and international diffusion of technology to relate an inventor's patenting decision to the underlying pattern of international technology diffusion. Section 3 describes our data and section 4 our empirical methodology and findings. In section 5 we offer some concluding remarks.

2 A Model of Innovation, Diffusion, and Patenting

Eaton and Kortum (1996) develop a model of international technology diffusion and patenting in which the number of patents filed by inventors from country i in country n, P_{ni}, decomposes into three fundamental factors: (i) *innovation*, α_i, the rate at which country i generates patentable inventions; (ii) *diffusion*, ϵ_{ni}, the fraction of innovations from country i that find a use in country n; (iii) the *propensity to patent*, f_{ni}, out of those innovations that diffuse, the fraction that are worth trying to patent.[6]

The theory itself is agnostic about the source of randomness in patenting. Since data on patent applications are counts and since they are generated by the individual decisions of many different inventors, we follow Hausman, Hall, and Griliches (1984) and treat them as the realization of a Poisson random variable with mean $\bar{P}_{ni}$ reflecting the combined impact of the three factors identified above,

$$\bar{P}_{ni} = \alpha_i \epsilon_{ni} f_{ni}.$$

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[6] The model implies that the propensity to patent f_{ni} depends on imitation rates (for both patented and unpatented innovations), the cost of patenting, and the size of country n's market. Eaton and Kortum (1996) relate the source country's rate of innovation α_i alternatively to its investment in research and to a country fixed effect. They relate diffusion rates ϵ_{ni} to the distance between i and n, imports from i to n, and the human capital of the receiving country n.

In the present paper, we apply this basic model to an individual technology class rather than to the aggregate. Adding a technological dimension retains the same decomposition into three fundamental factors, so that the number of patents in technology class c applied for by inventors from country i in country n has a Poisson distribution with mean $\bar{P}_{nic}$ given by:

$$\bar{P}_{nic} = f_{nic}\epsilon_{nic}\alpha_{ic} \quad n = 1, ..., N; \ i = 1, ..., I; \ c = 1, ..., C; \tag{1}$$

where N is the number of destination countries, I is the number of source countries (perhaps equal to the number of destinations), and C is the number of classes of technology. Here α_{ic} represents innovation in country i in technology class c, ϵ_{nic} is the fraction that diffuse to country n, and f_{nic} is the fraction of those inventions that are expected to be worth patenting.

While our theory identifies three factors determining patenting, the patent data themselves naturally have three dimensions as well: their source, their destination, and their technology class. Nonetheless, there is no unique correspondence between innovation, diffusion, and propensity to patent, on the one hand, and the source, destination, and technology class of a patent, on the other. The only implication of the theory so far is that innovative capacity in the source country is independent of the destination of its patents. We can, however, impose some plausible restrictions to tighten this correspondence in order to glean some inferences from the patent data.

To facilitate interpretation, but without imposing additional restrictions, we break country i's innovativeness in technology class c into factors that reflect country i's overall innovativeness, $\tilde{\alpha}_i$, total inventive activity in technology class c, $\tilde{\alpha}_c$, and a term that reflects country i's comparative advantage in producing innovations in technology class c, $\tilde{\alpha}_{ic}$. Thus $\alpha_{ic} = \tilde{\alpha}_i \times \tilde{\alpha}_c \times \tilde{\alpha}_{ic}$. Implicit in this decomposition and the ones that follow is a set of restrictions, in this case $\sum_{i=1}^{I} \ln \tilde{\alpha}_{ic} = 0 \quad c = 1, \ldots, C$ and $\sum_{c=1}^{C} \ln \tilde{\alpha}_{ic} = 0 \quad i = 1, \ldots, I$.

We are more restrictive in how we decompose diffusion and the propensity to patent. We break the diffusion term ϵ_{nic} into factors reflecting country n's overall ability to absorb technology, $\tilde{\epsilon}_n$, its relative ability to absorb technologies in class c, $\tilde{\epsilon}_{nc}$, its relative ability to absorb technologies from country i, $\tilde{\epsilon}_{ni}$, and other factors that depend on whether country n is the same as country i or not. To denote this last set of factors we introduce a superscript h where $h = 1$ if $n = i$ (as in domestic patents) and $h = 2$ if $n \neq i$ (as in foreign patents). Using this notation, overall differences in diffusion within and between countries are captured by $\tilde{\epsilon}^h$. To the extent that this home bias differs by technology class it is captured by $\tilde{\epsilon}_c^h$, and to the extent that it differs by destination country (the relative technological autarky of country n) it is captured by $\tilde{\epsilon}_n^h$. Hence $\epsilon_{nic} = \tilde{\epsilon}_n \times \tilde{\epsilon}_{ni} \times \tilde{\epsilon}_{nc} \times \tilde{\epsilon}^h \times \tilde{\epsilon}_n^h \times \tilde{\epsilon}_c^h$. Countries with a low value of $\tilde{\epsilon}_n^1$ (i.e., high values of $\tilde{\epsilon}_n^2$) are technologically more open while technologies with a low value of $\tilde{\epsilon}_c^1$ (i.e., high values of $\tilde{\epsilon}_c^2$) are internationally more mobile. Note that we treat diffusion as independent of, among other things, the source country (except as it interacts with the destination). Variation across sources in their ability to diffuse innovations is conceptually indistinguishable, within our model, from variation in their ability to innovate.

Finally, we break the propensity to patent term f_{nic} into factors reflecting country n's overall attractiveness as a place to patent, $\tilde{f}_n$, the overall propensity to patent in technology class c, $\tilde{f}_c$, an overall home bias in patenting, $\tilde{f}^h$, the relative home bias in patenting in country n, f_n^h, (possibly reflecting the extent to which country n's patenting system discriminates in favor of domestic inventors) and the home bias in patenting in technology class c, $\tilde{f}_c^h$. Hence $f_{nic} = \tilde{f}_n \times \tilde{f}_c \times \tilde{f}^h \times \tilde{f}_n^h \times \tilde{f}_c^h$. Note that, given our restrictions, the propensity to patent does not depend on the source (except that if the source is domestic the propensity may be higher).[7] This restriction is valid, for example, if all the costs and benefits of patenting are independent of the nationality of any foreign inventor. Thus we attribute all variation across foreign sources to differences in inventiveness. We also assume that the propensity to patent in a destination country does not vary across particular country-technology pairs (although it may vary by technology).

Under these restrictions the equation for the mean of patenting becomes:

$$\begin{aligned} \bar{P}_{nic} &= \tilde{f}_n \times \tilde{f}_c \times \tilde{f}^h \times \tilde{f}_n^h \times \tilde{f}_c^h \times \tilde{\epsilon}_n \times \tilde{\epsilon}_{ni} \times \tilde{\epsilon}_{nc} \times \tilde{\epsilon}^h \times \tilde{\epsilon}_n^h \times \tilde{\epsilon}_c^h \\ &\quad \times \tilde{\alpha}_i \times \tilde{\alpha}_c \times \tilde{\alpha}_{ic} \end{aligned} \tag{2}$$

for $n = 1, ..., N$; $i = 1, ..., I$; $c = 1, ..., C$; and $h = 1$ if $n = i$ ($h = 2$ otherwise). Although the dimension h is determined by the (n, i) pair, it is convenient to treat it as a fourth dimension of the data in what follows.

We can group the 13 terms on the right hand side of equation (2) into 9 sets of identifiable effects depending on: (1) the destination country D_n, (2) the source country S_i, (3) the technology class T_c, (4) the home effect H_h, (5) the interaction of the destination and source $(DS)_{ni}$, (6) the interaction of the destination and technology $(DT)_{nc}$, (7) the interaction of the source and technology $(ST)_{ic}$ (8) the interaction of the destination and the home effect $(DH)_{nh}$, and (9) the interaction of the technology and the home effect $(TH)_{ch}$.

Introducing an overall constant effect A, our equation becomes:

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[7] Patenting is likely to be more expensive and inconvenient for inventors from abroad since foreign filing requires engaging local counsel and often translation.

$$\bar{P}_{nich} = A \times D_n \times S_i \times T_c \times H_h \times (DS)_{ni} \times (DT)_{nc} \times (ST)_{ic} \times (DH)_{nh} \times (TH)_{ch}, \quad (3)$$

for $n = 1, ..., N$; $i = 1, ..., I$; $c = 1, ..., C$; and $h = 1$ if $n = i$ ($h = 2$ otherwise). These equations are subject to the restrictions:

$$\sum_{n=1}^{N} \ln D_n = \ldots = \sum_{h=1}^{2} \ln H_h = 0;$$

$$\sum_{n=1}^{N} \ln(DS)_{ni} = 0, \quad i = 1, \ldots, N, \quad \sum_{i=1}^{N} \ln(DS)_{ni} = 0, \quad n = 1, \ldots, N, \quad \ldots$$

$$\ldots \sum_{c=1}^{C} \ln(TH)_{ch} = 0, \quad h = 1, 2, \quad \sum_{h=1}^{2} \ln(TH)_{ch} = 0, \quad c = 1, \ldots, C;$$

and

$$\ln(DS)_{nn} = 0, \quad n = 1, \ldots, N.$$

Table 1 indicates the relationship between the parameters of the model, i.e. the various effects, (by row) and the three fundamental factors determining patenting (by column). Where a row of the table has only one element, the model parameter in that row reflects the indicated factor determining patenting. Hence overall source-country effects S_i reflect sources' importance in generating innovations $\tilde{\alpha}_i$ while source country effects interacted with technology class $(ST)_{ic}$ reflect comparative advantage in innovating within specific technologies $\tilde{\alpha}_{ic}$. Similarly destination interacted with source $(DS)_{ni}$ reflects patterns of diffusion $\tilde{\epsilon}_{ni}$ while destination interacted with technology $(DT)_{nc}$ reflects comparative ability to absorb technology $\tilde{\epsilon}_{nc}$. However, the overall destination effects D_n confounds destination n's ability to absorb innovation with its desirability as a place to patent while the overall technology effect T_c confounds the level of innovative activity in a technology with the propensity to take out patents in that technology. Note

Table 1: Interpretation of the Parameters

	propensity to patent	diffusion	innovation
D_n	$\tilde{f}_n$	$\tilde{\epsilon}_n$	
S_i			$\tilde{\alpha}_i$
T_c	$\tilde{f}_c$		$\tilde{\alpha}_c$
H_h	$\tilde{f}^h$	$\tilde{\epsilon}^h$	
$(DS)_{ni}$		$\tilde{\epsilon}_{ni}$	
$(DT)_{nc}$		$\tilde{\epsilon}_{nc}$	
$(ST)_{ic}$			$\tilde{\alpha}_{ic}$
$(DH)_{nh}$	$\tilde{f}_n^h$	$\tilde{\epsilon}_n^h$	
$(TH)_{ch}$	$\tilde{f}_c^h$	$\tilde{\epsilon}_c^h$	

finally that in order to infer the relative immobility of a technology $\tilde{\epsilon}_c^h$ from the technology class interacted with the home effect $(TH)_{ch}$ requires the additional restriction that $\tilde{f}_c^h$ is one, i.e., that there are no systematic differences across technologies in the extent to which inventors prefer to take out patents at home relative to abroad, given their pattern of diffusion. We now turn to the patent data themselves.

3 International Patenting by Technology

Before introducing our particular dataset, we take a broader look at international patent applications.[8] Table 2, based on data from the World Intellectual Property Organization (WIPO: 1970, 1977, 1993), shows the top 10 industrialized and top 4 developing countries in terms of foreign patent applications received. Among

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[8] The argument for looking at applications rather than grants is made in Griliches (1990). In the international context the case for using applications is even stronger, as we discuss in the appendix.

these countries, the United Kingdom, Germany, France, the United States, and Japan are consistently at the top. The analysis below considers only these five as destinations for patents, although we include applications originating from anywhere in the world. A consequence of this focus is that we ignore applications for patents in developing countries. But, as Table 2 makes clear, these countries generally receive far fewer applications than developed countries.

In general countries obtain more applications from foreign residents than from their own residents. The extreme example is Belgium where foreign applications dominate domestic applications by a factor of ten in 1970 and 1977 and by even more in 1993. The anomaly is the Japanese who seek vast numbers of patents locally. It turns out that these applications contain few claims of invention, and we account for this in all the subsequent analysis by scaling down Japanese domestic applications by a factor of 4.9.[9] The tendency for countries to receive most of their patent applications from abroad has become more pronounced over time. This increased globalization of patenting has occurred mostly after 1977, however. We now turn to our primary interest, which is the technological dimension of the patent data.

We analyze patent counts cross-classified by source country (the country of inventor), destination country (the country where patent protection is sought), and the class of technology patented. The technological dimension comes from a dataset assembled at Yale's Economic Growth Center based on extracts from files

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[9] Okada (1992) finds that Japanese domestic patents contain only 1/4.9 or approximately 20 per cent as many claims on average as do foreign priority patents in Japan. There is no evidence that Japanese patents abroad are similarly anomalous, probably because patent laws in other countries encourage the bundling of related claims into a single application.

Table 2: Countries Receiving the Most Patent Applications from Abroad

Country	Applications in 1970		Applications in 1977		Applications in 1993	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Top 10 Countries						
United Kingdom	25227	36874	21114	33309	24401	76841
Germany	32772	33360	30247	30154	46865	70903
France	14106	33177	11811	28167	16042	66099
United States	72343	30832	62863	38068	102245	89141
Japan	100511	30318	135991	25015	332460	47575
Canada	1986	28524	1832	23337	4067	43685
Italy	7241	24587	n/a	n/a	9040	56130
Netherlands	2462	16647	1960	12669	3825	54997
Belgium	1339	15848	1073	11453	1438	45082
Sweden	4343	13515	4503	10476	5417	50224
Top 4 Developing Countries						
South Africa	2428	6316	2966	4762	5347	4460
Brazil	3839	5385	1645	7071	2467	14477
Argentina	1982	5096	1704	2800	n/a	n/a
India	1278	3864	n/a	n/a	1209	2511

Source: WIPO (1970, 1977, 1993). The countries are ordered by the number of foreign patent applications in 1970. A different set of developing countries would top the list if we were to use the 1993 data.

of the European Patent Office (EPO). The unique aspect of this dataset is that each patent is assigned to an International Patent Class (IPC).[10] We aggregate the 100,000 IPC classifications into 23 groups, as defined in Table 3.[11]

We focus on a subset of the Yale data covering all patents that were applied for in 1977 (with a comparison made to 1970) and that were eventually published in one of five industrial countries: France, Germany, Japan, the United Kingdom, and the United States.[12] We consider patenting from all source countries, but after aggregating smaller countries we end up with 17 distinct sources.[13]

One difficulty in using the Yale data for cross-country comparisons is that there is no international standard definition of a published patent.[14] Another difficulty

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[10] The appendix provides details about the Yale data. The Yale-Canada Concordance [Kortum and Putnam (1997)] augments these data by assigning patented inventions to their industries of origin and use based on the IPC assignment. Here we analyze the international patent data as they come from the EPO.

[11] The composition of each of our technology classes is taken from WIPO (1994) with one additional category created for pharmaceuticals.

[12] The appendix describes our proxy for the year of application. We narrow our analysis to the years 1970 and 1977 to avoid complications arising from the introduction of the European Patent in 1978 and because the first year of complete data is 1970. In order to use the data after 1977 we must merge in all patents published by the EPO (by date of application) according to the destination countries designated on each patent. This task is not yet complete.

[13] Our source countries (and regions) are 01_FR = France; 02_GE = Germany; 03_UK = United Kingdom; 04_US = United States; 05_JA = Japan; 06_AT=Austria; 07_BE=Belgium and Luxembourg; 08_IT = Italy; 09_NT = the Netherlands; 10_SZ=Switzerland; 11_SC=Scandanavia (excluding Sweden); 12_SW=Sweden; 13_OE=Greece, Ireland, Israel, and Spain; 14_AU=Australia and New Zealand; 15_CA = Canada; 16_SV=Soviet Block; and 17_OT=Africa, Asia (excluding Japan), and South America. Note that all developing countries are included in 17_OT.

[14] In the United States (and prior to 1978 in the United Kingdom as well) it corresponds to a patent application that has survived a lengthy period of examination, while in the other three

Table 3: Technology Groupings

	Definition of Grouping	Component Classes of the IPC
Ag	Agriculture	A01 (less A01N)
Fo	Foodstuffs	A21-A24
Pe	Personal or domestic	A41-A47
He	Health and amusement	A61-A63 (less A61K)
Ph	Pharmaceuticals	A61K
Se	Separating and mixing	B01-B09
Sh	Shaping	B21-B32 (less B31)
Pr	Printing	B41-B44
Tr	Transporting	B60-B68
Ch	Chemistry	C01-C14 (plus A01N, less C06)
Me	Metallurgy	C21-C30
Te	Textiles and other	D01-D07
Pa	Paper	D21 (plus B31)
Bu	Building	E01-E06
Dr	Drilling and mining	E21
Pu	Pumps and engines	F01-F04
En	Engineering	F15-F17
Li	Lighting and heating	F21-F28
We	Weapons and blasting	F41-F42 (plus C06)
In	Instruments	G01-G12
Nu	Nucleonics	G21
El	Electricity	H01-H05
XX	Other	other

has to do with the definition of the source country. The problem is that the Yale data identify the source as the country where patent protection is first sought, which may differ from the residence of the inventor.[15]

International patent application data from WIPO avoid both of these problems. Patent applications do have an international standard definition and the inventor's country of residence is identified as the source. For this reason, we use WIPO application data by source and destination country as the basis for benchmarking the Yale data.[16] This amounts to scaling the Yale data so that totals by source and destination country match the totals published by WIPO. Tables A.1 and A.2 compare (in 1970 and 1977 respectively) the Yale with WIPO data classified by source and destination country (note the small number of patent applications from the developing-country sources, 17_OT). The scaling factor in 1977 for destination-France by source-France is 0.94 while for destination-France by source-Germany it is 1.05. In the United States many patent applications never make it through the examination process to become published, hence the scaling factor for destination-United States by source-Germany, for example, is 1.52 in 1977. The analysis in the remainder of the paper is based on the Yale data benchmarked in this way.

The benchmarked Yale data contain 1955 cells (observations) in 1977 (5 destination countries by 17 source countries by 23 technologies). The total number of

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countries it is essentially a rubber stamp that follows the date of application by 18 months (see the appendix for details).

[15] Putnam (1996) models the choice of first-filing (priority) country, which depends on the relative size of the foreign and domestic fee schedules and markets, and the quality of the patent office's initial signal regarding patentability. In the case of Canadian and Belgian inventors, 75 per cent of all patents are filed first outside the inventor's country of residence.

[16] In principle one could use the WIPO data disaggregated by technology class. This is not feasible in practice, however, due to a preponderance of missing values.

patents across all these observations is 308501. There are 119 observations with zero patents. This forms our main dataset for analysis. We conclude by comparing the stability of results between 1970 and 1977. To do this we drop Japan as a destination since those data are not available in 1970.

4 A Decomposition of the International Patent Data

We estimate the parameters of equation (3) by maximum likelihood under the assumption that observed patenting, P_{nich}, is the realization of an independently distributed Poisson random variable with mean $\bar{P}_{nich}$.[17] Note that by adding the home dimension h we have a table with $N \times I \times C \times 2$ observations, half of which are structural zeros (i.e., we set $P_{nich} = 0$ in the cases of $n = i$ and $h = 2$ or $n \neq i$ and $h = 1$). The theory of log-linear models for cross-classified categorical data suggests an iterative algorithm for obtaining the maximum likelihood estimates in tables with structural zeros.[18] The theory also provides a framework for testing restrictions of the model and assessing its overall fit.

We begin by estimating the model on the 1977 patent data (with 3910 observations, 1955 of which are structural zeros). Before presenting the parameter estimates we provide a brief discussion of how well our basic model fits and the contribution of each set of effects on the margin. We then turn to the parameters themselves, presented in a series of tables. We conclude with tests for differences between the parameters in 1977 and 1970.

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[17] We ignore any correlation induced by the fact that the same invention is often patented in several countries.

[18] See, for example, Bishop, Fienberg, and Holland (1975) or Christensen (1990).

4.1 The Fit of the Model

We can test various models (k) by evaluating the maximum likelihood estimates, $\hat{P}^{(k)}_{nich}$, of the Poisson means $\bar{P}_{nich}$. An interesting feature of the Poisson assumption is that we can estimate a model with no restrictions whatsoever on $\bar{P}_{nich}$. This is called the saturated model s, and the maximum likelihood estimates of the Poisson means are simply $\hat{P}_{nich} = P_{nich}$. The likelihood ratio statistic for testing the null hypothesis of model (k) against the alternative of the saturated model is,

$$G^2(k) = 2\sum P_{nich} \ln(P_{nich}/\hat{P}^{(k)}_{nich}),$$

where the summation is over all observations that are not structural zeros (note that for the saturated model $G^2(s) = 0$). This statistic has a χ^2 distribution with *df* degrees of freedom under the null hypothesis that model k is correct, where *df* equals the number of observations less the number of structural zeros less the number of parameters in model k, (net of the number of restrictions).[19]

The likelihood ratio statistic $G^2(k)$ and degrees of freedom *df* for a number of models k are presented in Table 4 below. The models are identified according to the highest levels of interaction effects that they contain. The first is the saturated model, s, which allows for a full set of interactions between destination country, source country and technology (note that this set of interactions subsumes any interactions with home). The second model, 0, is the most restrictive and allows for only one dimensional effects (Source, Destination, and Technology Class). The third row represents the baseline model (model 1) as in equation (3). Each of the last four models (models 2-5) represents various restrictions on the baseline

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[19] The test requires non zero patenting in each cell so in calculating the test statistics we add 0.1 patents to each observation with no patents.

model (i.e. a different set of effects is removed in each). Normally the destination-country by home effects are subsumed in the destination-country by source-country effects. In model 2, however, where we remove source country effects, we include destination-country by home effects.

The test statistics indicate that any restrictions on the saturated model can be rejected, including the restrictions imposed by our baseline model. This means that there is a statistically significant interaction between technology and destination-country by source-country interactions that is not completely captured by the technology-home effects. A higher-order interaction of this sort may be statistically significant, even if it has little economic importance, so we investigate further. An analog of the coefficient of determination in a typical regression equation can be calculated by taking the percentage reduction in G^2 relative to a very restrictive model such as model 0. Hence, following Christensen (1990), we define $R^2(k) = [G^2(0) - G^2(k)]/G^2(0)$, hence $R^2(0) = 0$ and $R^2(s) = 1$. The R^2 values are a heuristic device for assessing the fit of the various models. These values are shown in the second-to-last column of Table 4. The baseline model explains about 90 per cent of the variation remaining after all one-dimensional effects have been removed. We also see that model 3 (which excludes destination-country by technology effects) also does quite well. In contrast, the model that excludes source-country by technology effects explains less than half of the residual variation in the data. This suggests that technological specialization in innovation is a more important phenomenon than the technological specialization in absorption of technology.

One problem with drawing conclusions from R^2 is that it does not take account of the number of parameters in each model. We therefore turn to Akaike's

Table 4: Model Fit

k	Model	Configuration	*df*	$G^2(k)$	$R^2(k)$	AIC(k) $-q$
s	saturated model	[DST]	0	0	1.00	0
0	most restrictive	[D][S][T][H]	1911	58719	0.00	54897
1	baseline Model	[DS][DT][ST][TH]	1385	6346	0.89	3576
2	no dest.-source	[DH][DT][ST][TH]	1445	13825	0.76	10935
3	no dest.-tech.	[DS][ST][TH]	1473	9835	0.83	6889
4	no source-tech.	[DS][DT][TH]	1737	30641	0.48	27167
5	no tech.-home	[DS][DT][ST]	1407	12919	0.78	10105

information criterion (AIC) to compare the statistical information contained in each model. Letting q be the number of observations less the number of structural zeros, Christensen (1990) shows that $AIC(k) - q = G^2(k) - 2(df)$ (with low values preferred and the saturated model having a value of 0). This calculation is performed in the last column of the table. The saturated model is still preferred to our baseline model. Furthermore, of the various restricted versions of the baseline model (none of which are preferred to the baseline model itself) the model without destination-country by technology effects is most preferred and the model without source-country by technology effects is least preferred. Thus, again we conclude that technological specialization in innovation is a particularly important phenomenon. We now turn to the parameters estimated for the baseline model.

4.2 Parameter Estimates

We present the parameter estimates in a series of 9 tables. Each table corresponds to one of the 9 sets of effects entering equation (3). The parameters are multiplicative effects and should be interpreted relative to a mean of 1. Since the parameter estimates satisfy the identifying restrictions listed beneath equation (3), the geometric means of all rows and columns are equal to 1.[20] Note also that the diagonal elements of the destination-country by source-country table are each unity.

The estimation methodology we follow allows for observations with zero patent counts. It does, however, require that any summary table have all strictly positive counts. This was an issue, in our case, only for the summary table of source-country by technology in which we had 7 zero entries. We simply added 0.1 patents to each of the 35 observations contributing to these 7 zero entries. We now turn to estimates of the effects themselves. We begin by discussing overall destination country effects.

4.2.1 Destination-Country Effects

How important were our five countries as destinations for foreign patents in 1977? The first set of effects, reported in Table A.3, provides an answer. The D effects are purged of any influences due to the importance of each country as a source. They are also purged of the influence of any bias against patents from abroad as that bias might vary by country.

Note that in 1977 Japan was relatively small as a destination for foreign patenting, while the United Kingdom was the largest destination. The model attributes the higher number of foreign patents received by the United States to the (DH) effects shown below (indicating that the U.S. was relatively open to patenting

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[20] For example, in the case of destination-country effects (where the table is a single column),

$$\prod_{n=1}^{N}(\hat{D}_n)^{1/N} = e^{(1/N)\sum_{n=1}^{N}\ln \hat{D}_n} = e^0 = 1,$$

where $\hat{D}_n$ is the maximum likelihood of D_n.

from abroad) rather than to the overall attractiveness of the U.S. as a destination. The key insight from this table is that differences among the countries along this dimension are surprisingly small, the maximum difference being a factor of two.

4.2.2 Source-Country Effects

How much do countries differ as sources of patents? Table A.4 reports estimates of the S effects. Even among the first five countries the variation by source is substantially greater than the variation by destination. In particular, the United States and Germany stand out as powerful innovators, with the United States leading France by a factor of over 4. All other countries are far behind. This result corroborates Evenson's (1984) finding that the sources of world patents are highly concentrated.

4.2.3 Technology Effects

Table A.5 reports differences in overall patenting levels according to technology classes (the T effects). The differences across classes are substantial with chemistry, electricity, instruments, and transporting being the big technologies for patenting.[21] Agriculture is moderately sized with building technologies somewhat bigger. Nucleonics, paper, and weapons are the smallest technologies for patenting. Surprisingly, pharmaceuticals is also small but this could be because many

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[21] While these patterns generally mirror the allocation of R&D by industry, differing appropriability and regulatory conditions render this correlation less than unity. For example, the aerospace industry—which comprises parts of electricity, instruments, weapons, and transporting—is highly R&D intensive and highly innovative, but has a low propensity to patent. Recall from Table 1 that we are unable to discriminate between technology-specific propensities to patent and technology-specific innovativeness.

drug patents are showing up in other categories such as chemicals.

4.2.4 Home Effects

Table A.6 reports the estimates of the overall H effect. Note that home patenting dominates foreign patenting by a factor of over 6. As we will see below this home bias does not vary widely by country although there is an illuminating pattern in how it varies across technologies.

4.2.5 Destination-Country by Source-Country Effects

Once the vast differences between overall home and foreign patenting are taken into account, source and destination effects alone do a remarkable job in explaining cross-country patterns of patenting. This can be seen in the estimates of the (DS) parameters. The cross-country terms reported in Table A.7 cluster quite closely around one.[22] The big exception is the link from Canada to the United States, which is more than three times what would be implied by the null that source and destination effects explain everything. Other links that one would expect to be strong on *a priori* grounds, such as from Austria to Germany or from Belgium-Luxembourg to France, also stand out. Among our five destination countries, the diffusion link from Japan to France is particularly weak while the link from Japan to the United States is particularly strong. These diffusion links need not obey symmetry, for example note the average sized diffusion link from France back to Japan.

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[22] This result provides some vindication for the assumption, in Eaton and Kortum (1997), that diffusion effects could be broken down into source, destination, and home effects.

4.2.6 Destination-Country by Technology Effects

Table A.8 reports the parameters of the relative attractiveness of the five destination countries as places to patent different technologies. We interpret these (DT) effects as reflecting the relative abilities of these countries to absorb different types of technology. The major observation is that, in comparison with the source-country by technology effects that we turn to next, there is only modest variation across either rows or columns. Two outliers are Japan, first as a destination for patents in nucleonics, where it is big, and in agriculture, where it is small. As for technologies, the most variable is weapons, which is about three times more popular in the United States than in Japan. But the basic message is that these five countries do not differ that much in terms of their affinity for different technologies.

4.2.7 Source-Country by Technology Effects

In Table A.9 we report the parameters that describe the relative inventiveness of different countries in different technologies. These (ST) effects can be interpreted as indicators of the revealed comparative advantage of different countries in different technologies. We see a considerable degree of specialization. Note for instance the specialization of Japan in instruments, of Belgium-Luxembourg in metals and pharmaceuticals, of Italy and Switzerland in textiles, of the Netherlands and Australia-New Zealand in agriculture, and of Scandinavia in paper. We see that small countries tend to specialize more than large ones, corroborating Archibugi and Pianta's (1992) finding.

How important are different countries absolutely as innovators in different technologies, not correcting for their overall level of patenting? The answer can be found by multiplying the overall source-country effects in Table A.4 with the appropriate source-country by technology effects in Table A.7. This exercise reveals, for example, that in absolute terms the United States dominates innovations in paper, although Scandinavia's contribution remains significant.

4.2.8 Destination-Country by Home Effects

How much do our five destinations vary in their preference for home patenting? Relative to the extreme preference for patenting at home displayed overall, the variation in this home preference across countries is minor. Table A.10 indicates that Japan is about 30 per cent more closed than average, while the United States is about 20 per cent more open.

4.2.9 Technology by Home Effects

As discussed above, a technology's home bias provides some insight into its geographical immobility, especially if the home bias in the propensity to patent does not vary across technologies. According to Table A.11, chemicals and pharmaceuticals are the most cosmopolitan technology classes, with agriculture and building the most parochial. But, given the vast overall home bias in patenting, the extent of variation in that bias across individual technologies is relatively small: The most local technology has about twice the home bias of the most international technology.

4.2.10 Higher-Level Effects

Since our statistical tests suggest that there may be some higher-level interactions that the model fails to capture, we conclude by examining large values of standardized residuals, defined as $[P_{nich} - \hat{P}^{(1)}_{nich}]/[\hat{P}^{(1)}_{nich}]^{1/2}$. Extreme values of the standardized residuals (the residuals divided by an estimate of their standard errors, according to the model) are likely to be observations that are influenced by higher-order interactions not captured by our baseline model. There are 4 cases in which the absolute value of the standardized residual exceeds 9 (a substantial outlier relative to the model). Interestingly, 3 of these involve chemicals patents. The model over-predicts chemical patent applications in France by Germans (predicted = 1356, actual = 1004), it underpredicts them in France by the Japanese, and it overpredicts them in Japan by the Japanese. The last case involves applications for patents on drilling technology in Japan by Scandinavians (prediction=0.4, actual=7).

4.3 Changes over Time

How sensitive are our findings to the choice of year and which sets of effects change the most over time? Here we compare the parameter estimates in 1970 and 1977, with Japan dropped as a destination. So little changes across these time periods that we can summarize the results quite briefly. The only specific changes worth remarking upon are a noticeable slide in the relative importance of the United States and the United Kingdom as sources and a rise in the importance of Japan. The technology effects are stable except for a big rise in the relative importance of pharmaceuticals.

For each set of effects, we also tested the hypothesis of stability over time, allowing all the other effects to vary with time. We can always reject the hypothesis of stability in a statistical sense even though the changes appear to be trivial in terms of their quantitative importance. Using the AIC criterion, the model with stable technology by home-country effects is second best to the model in which all effects vary with time. This result suggests that our finding about the relative mobility of different technologies is a particularly robust one.

5 Conclusion

We have made use of a new set of data on international patents to study the technological dimension of international patenting. Several results are noteworthy. A major finding is that destination effects are much less important than source effects in explaining patenting in different technologies. While the five destination countries seem to take advantage of the entire spectrum of technologies, technological diffusion allows them to be somewhat specialized in the technologies in which they innovate. Smaller countries are even more specialized in their production of technology.

Another finding is that diffusion links between countries follow a simple pattern. Once the size of the source, the attractiveness of the destination, and the bias toward patenting at home are accounted for, there is little left to be explained. The home-bias itself is substantial, suggesting that many innovations have little effect outside their country of origin. This bias does not differ that much by country but there is an interesting variation across technologies. Chemical and pharmaceutical technologies appear to be the most mobile, with agriculture and building technologies being the least.

The purpose of our analysis here has been to scrutinize international patent data to see what they have to say about comparative advantage in research and about technological mobility. We have not attempted here to link these numbers to international data on research effort, sectoral productivity, or patterns of trade. To date, these other data have received much greater attention. We think that the patent data provide fresh evidence about the role of technological diffusion in economic growth. As developing countries become increasingly important destinations for patents [WIPO (1993)] future work might exploit patent data to discern what types of ideas developing countries make use of and where they are getting them from.

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A The Yale Data on International Patenting

In the Yale data each patent is assigned to an International Patent Classification (IPC) code, a reporting country (i.e. a destination country), a priority country (which proxies for the source country), a year of publication, and a year of first filing. We will discuss the definitions of these concepts and how they relate to their analogs in the data from the World Intellectual Property Organization (WIPO).

A.1 Comparability Across Countries

The Yale data consist of published patents. The exact meaning of published patents differs across countries. Sticky issues of comparability across countries arise because we do not have data on patent applications that are never published.

Countries generally follow either the European system or the U.S. system of patent examination and publication after application. In the European system, there are two stages of patent publication. The first publication takes place routinely 18 months after the date of application; at this stage the patent has not been screened in great detail. It is after this stage that patents show up in the Yale data. After the first publication, the inventor has to apply for further examination. If the patent is accepted after the second examination, then it is published for a second time and it can be considered a granted patent. This second publication may occur many years after the date of application. For example, almost 40% of patents granted in France in 1992 were applied for prior to 1988 (WIPO (1994)).

In the U.S. system a patent is published only after the application has been examined and accepted. A patent is generally granted within two or three years of the date of application. For example, less than 15% of patents granted in the

United States in 1992 were applied for prior to 1990 (WIPO(1994)). The screening before publication in the U.S. is comparable to the screening before the second publication in the European system.

A.2 Priority Country

The priority country is the country in which the inventor first sought patent protection. If inventors generally choose to protect their innovations first at home, then the priority country is a good indicator of the residence of the inventor. To check this assumption, we compare patenting by priority country with patenting by residence of inventor (published by WIPO) and find that totals by priority country are similar to totals by country of residence. In Table A.1 one can see the similarity, for example for French-destination patents, between the Yale data (where the source country is the priority country) and the WIPO data (where the source country is the residence of the inventor).

A.3 Priority Year

The priority year of a patent is the year of application in the priority country. There is also a year of publication specified with each patent. We use the priority year to organize and analyze the Yale data because the year of publication must be interpreted in different ways depending on whether a country follows the European or the U.S. system of publication.

A further distinction arises between priority year and year of application. In a given destination country, the year of application for domestic patents is the same as the priority year whereas the year of application for foreign patents is generally one year after the priority year. After the priority application is filed, the inventor has one year to apply for protection in other countries. Inventors seem to use this one year grace period rather than filing additional applications immediately. To facilitate comparisons with WIPO data on patent applications by year of application we proxy for year of application by adding one year to the priority year for foreign priority patents.

A.4 Comparisons with Aggregate Data from WIPO

In this section we show how the two datasets line up. Tables A.1 and A.2 compare patent application data by year of application and country of residence from WIPO with the Yale patent publication data using our proxy for year of application and using priority country as a proxy for the source. Notice that in each destination country under the European system (France, Germany, and Japan) the Yale totals are only slightly below the WIPO totals. We believe the difference represents those patents which fail the screening that precedes the initial publication. For countries that follow the U.S. system of examination and publication (the United States and the United Kingdom prior to 1978), a much greater fraction of patents have failed the standard for publication.[23]

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[23] Comparing patents published by year of publication from the Yale data with patents granted by year of grant from WIPO data, we obtained a very close match in the United States and the United Kingdom. This is consistent with our interpretation of a published patent in the U.S.-system countries.

Table A.1
Comparisons of Patent Counts from WIPO and Yale for 1970

	Destination Country									
	01_FR		02_GE		03_UK		04_US		05_JA	
	Data Source		Data Source		Data Source		Data Source		Data Source	
	WIPO	YALE	WIPO	YALE	WIPO	YALE	WIPO	YALE	WIPO	YALE
Source Cty.	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70	Pat. Ct.70
01_FR	14106	16275	3040	3020	2546	2329	2375	1670	1354	.
02_GE	8416	8319	32772	31579	7761	6450	6808	4369	5901	.
03_UK	3072	3370	3623	3875	25227	11018	4113	2489	2485	.
04_US	11538	9346	12618	10981	14057	10815	72343	54146	13805	.
05_JA	2526	2505	3838	3984	3592	3287	5295	4184	100511	.
06_AT	317	383	638	759	294	273	322	238	233	.
07_BE	526	393	407	333	408	210	307	147	226	.
08_IT	1015	1216	1064	1138	958	756	1017	585	455	.
09_NT	1134	899	1334	976	819	828	738	568	985	.
10_SZ	2041	1608	2890	1998	2000	1225	1506	1016	1744	.
11_SC	286	202	520	362	594	270	429	181	225	.
12_SW	630	666	971	935	843	700	806	533	592	.
13_OE	233	204	188	180	275	121	276	81	87	.
14_AU	95	115	138	130	324	187	315	130	154	.
15_CA	256	110	318	142	677	173	1535	237	308	.
16_SV	1563	1017	1327	1771	1151	474	700	253	866	.
17_OT	335	95	398	116	595	133	467	106	642	.

Table A.2
Comparisons of Patent Counts from WIPO and Yale for 1977

	Destination Country									
	01_FR		02_GE		03_UK		04_US		05_JA	
	Data Source		Data Source		Data Source		Data Source		Data Source	
	WIPO	YALE	WIPO	YALE	WIPO	YALE	WIPO	YALE	WIPO	YALE
	Pat.	Pat.	Pat.	Pat.	Pat.	Pat.	Pat.	Pat.	Pat.	Pat.
	Ct.77	Ct.77	Ct.77	Ct.77	Ct.77	Ct.77	Ct.77	Ct.77	Ct.77	Ct.77
Source Cty.										
01_FR	11811	12614	2761	2492	2467	2096	3007	2051	1488	875
02_GE	7420	7064	30247	29272	6749	5902	8903	5851	5094	2926
03_UK	2159	2512	2573	2726	21114	12282	4533	2678	1762	1002
04_US	8637	7050	10283	8230	11580	8958	62863	41667	10836	5122
05_JA	2345	2285	4626	4416	3601	3429	9674	6810	27753	27392
06_AT	287	322	605	600	258	221	402	281	196	79
07_BE	443	341	358	308	347	250	415	251	175	50
08_IT	1059	1110	1106	1081	855	828	1224	671	478	335
09_NT	1097	712	1190	788	1104	714	1026	585	879	317
10_SZ	1838	1182	2611	1726	1732	1002	1964	1139	1433	365
11_SC	363	234	598	393	760	285	618	239	320	95
12_SW	704	646	989	895	846	739	1253	710	610	176
13_OE	281	186	254	157	361	142	434	139	131	78
14_AU	125	125	165	164	362	275	524	271	173	67
15_CA	198	96	260	102	695	143	2192	293	259	74
16_SV	871	490	1388	894	838	403	1024	309	749	114
17_OT	340	92	387	99	754	117	875	134	432	247

Table A.3
1977 Data

Destination Country	Effect
01_FR	0.9
02_GE	0.9
03_UK	1.3
04_US	1.2
05_JA	0.8

Estimates of D parameters

Table A.4
1977 Data

Source Country	Effect
01_FR	2.5
02_GE	7.2
03_UK	2.8
04_US	11.0
05_JA	3.1
06_AT	0.3
07_BE	0.3
08_IT	0.8
09_NT	0.8
10_SZ	1.7
11_SC	0.5
12_SW	1.0
13_OE	0.3
14_AU	0.3
15_CA	0.5
16_SV	0.8
17_OT	0.5

Estimates of S parameters

Table A.5
1977 Data

	Effect
Technology	
Ag_Agricult	1.0
Bu_Building	2.6
Ch_Chemist	5.2
Dr_Drilling	0.3
El_Electric	4.2
En_Engineer	1.7
Fd_Food	0.7
He_Health	1.8
In_Instrum	4.6
Li_Lighting	1.7
Me_Metals	1.2
Nu_Nucleon	0.1
Pa_Paper	0.2
Pe_Personal	1.4
Ph_Pharmac	0.4
Pr_Printing	0.7
Pu_PumpsEng	1.2
Se_Separate	1.6
Sh_Shaping	3.6
Te_Textiles	1.0
Tr_Transpor	4.5
We_Weapons	0.3
XX_Other	0.0

Estimates of T parameters

Table A.6
1977 Data

	Effect
Domestic or Foreign	
DO	2.6
FO	0.4

Estimates of H parameters

Table A.7
1977 Data

	Destination Country				
	01_FR	02_GE	03_UK	04_US	05_JA
Source Country	Effect	Effect	Effect	Effect	Effect
01_FR	1.0	1.2	1.0	0.9	1.0
02_GE	1.3	1.0	0.9	0.8	1.0
03_UK	1.0	0.9	1.0	1.1	0.9
04_US	0.9	0.9	0.9	1.0	1.3
05_JA	0.7	1.1	0.8	1.6	1.0
06_AT	1.1	1.7	0.7	0.8	0.9
07_BE	1.7	1.1	1.0	0.8	0.7
08_IT	1.4	1.2	0.9	0.9	0.8
09_NT	1.3	1.0	1.0	0.6	1.2
10_SZ	1.2	1.3	0.8	0.7	1.1
11_SC	0.8	1.1	1.4	0.8	1.0
12_SW	1.0	1.1	0.9	1.0	1.1
13_OE	1.2	0.9	1.2	1.0	0.8
14_AU	0.6	0.7	1.4	1.5	1.2
15_CA	0.5	0.5	1.4	3.2	0.8
16_SV	1.1	1.4	0.8	0.7	1.1
17_OT	0.8	0.7	1.3	1.1	1.3

Estimates of DS parameters

Table A.8
1977 Data

	Destination Country				
	01_FR	02_GE	03_UK	04_US	05_JA
	Effect	Effect	Effect	Effect	Effect
Technology					
Ag_Agricult	1.5	1.0	1.0	1.2	0.5
Bu_Building	1.2	1.0	1.0	1.1	0.8
Ch_Chemist	0.9	0.9	0.9	1.0	1.4
Dr_Drilling	0.9	1.1	1.2	1.3	0.6
El_Electric	0.9	1.0	0.9	0.9	1.5
En_Engineer	1.1	1.0	1.1	0.9	1.0
Fd_Food	1.1	0.9	0.9	0.8	1.5
He_Health	1.0	1.0	0.9	1.1	1.0
In_Instrum	0.9	1.0	0.9	1.0	1.3
Li_Lighting	1.1	1.0	0.9	0.9	1.1
Me_Metals	1.0	0.9	0.9	0.9	1.5
Nu_Nucleon	0.9	0.9	0.8	0.7	2.2
Pa_Paper	1.0	0.9	0.8	0.9	1.3
Pe_Personal	1.3	1.0	1.0	1.1	0.7
Ph_Pharmac	0.9	0.8	0.8	0.9	1.9
Pr_Printing	1.1	0.9	1.0	0.8	1.3
Pu_PumpsEng	1.0	1.0	1.0	1.1	0.9
Se_Separate	1.0	1.0	0.9	1.0	1.1
Sh_Shaping	1.0	0.9	0.9	0.9	1.3
Te_Textiles	1.0	1.0	1.0	1.0	1.1
Tr_Transpor	1.1	1.0	1.0	1.0	1.0
We_Weapons	1.1	0.9	1.2	1.5	0.5
XX_Other	0.5	2.6	3.3	1.2	0.2

Estimates of DT parameters

Table A.9
1977 Data

	Source Country									
	01_FR	02_GE	03_UK	04_US	05_JA	06_AT	07_BE	08_IT	09_NT	10_SZ
	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.
Technology										
Ag_Agricult	0.7	0.6	0.5	0.5	0.4	1.6	0.3	0.8	6.5	0.4
Bu_Building	0.7	0.7	0.4	0.4	0.5	2.6	1.2	1.1	1.1	0.7
Ch_Chemist	0.9	1.1	1.4	1.4	1.2	0.8	3.2	1.3	0.8	1.4
Dr_Drilling	1.2	1.6	1.6	1.8	0.7	1.7	1.6	0.2	1.2	0.2
El_Electric	1.3	1.2	1.1	1.5	2.5	0.6	0.4	1.2	3.3	1.0
En_Engineer	1.4	1.4	1.1	1.1	0.9	0.9	0.4	1.2	1.5	1.1
Fd_Food	0.8	0.5	0.9	0.9	0.9	0.7	1.1	1.2	1.9	1.4
He_Health	0.8	0.8	0.8	1.2	0.6	2.5	0.7	0.7	0.9	0.9
In_Instrum	1.1	1.1	1.1	1.5	3.0	0.6	0.7	1.1	1.7	1.4
Li_Lighting	0.9	0.8	0.7	0.8	0.8	0.9	1.3	1.4	0.9	1.1
Me_Metals	0.7	0.6	0.8	0.9	1.6	0.9	4.3	0.7	0.7	0.8
Nu_Nucleon	3.0	3.4	1.7	2.9	3.0	2.3	0.7	0.0	1.9	0.4
Pa_Paper	0.8	0.9	1.1	1.0	0.6	0.3	0.1	1.1	1.2	2.1
Pe_Personal	0.7	0.8	0.5	0.8	0.6	0.8	0.9	2.4	0.6	1.2
Ph_Pharmac	1.3	0.8	1.7	1.4	1.0	0.3	4.9	1.7	0.9	1.0
Pr_Printing	0.9	1.2	0.8	1.1	2.4	0.7	1.3	1.4	0.5	1.5
Pu_PumpsEng	1.3	1.6	1.2	1.1	1.9	1.5	0.6	1.5	0.2	1.1
Se_Separate	0.8	1.0	1.1	1.1	0.8	1.1	1.1	0.7	1.1	1.0
Sh_Shaping	0.7	0.9	0.7	0.7	1.0	1.6	1.0	1.5	0.9	1.1
Te_Textiles	0.7	1.1	1.1	0.7	1.2	1.1	0.6	3.1	0.6	3.3
Tr_Transpor	1.0	1.1	0.9	0.8	0.8	0.9	0.6	1.5	1.1	1.0
We_Weapons	1.1	1.1	0.5	0.7	0.2	0.5	2.9	1.0	0.5	2.0
XX_Other	2.1	0.8	5.0	0.9	1.9	2.4	6.6	2.1	0.3	1.0

(CONTINUED)

Estimates of ST parameters

Table A.9
1977 Data

	Source Country						
	11_SC	12_SW	13_OE	14_AU	15_CA	16_SV	17_OT
	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.	Eff.
Technology							
Ag_Agricult	3.1	1.3	1.7	4.2	0.6	1.3	1.1
Bu_Building	2.1	1.2	2.2	1.3	1.7	0.4	1.8
Ch_Chemist	0.6	0.3	1.0	0.4	0.8	1.9	0.9
Dr_Drilling	0.4	2.7	0.4	0.4	3.1	2.2	3.0
El_Electric	0.9	0.7	0.5	0.5	1.3	1.2	0.9
En_Engineer	1.6	1.5	1.0	0.7	0.8	0.9	0.7
Fd_Food	0.9	0.8	1.1	1.3	1.4	0.9	0.8
He_Health	1.4	1.2	1.8	1.3	0.8	0.6	1.5
In_Instrum	0.8	0.8	0.5	0.8	0.7	1.4	0.7
Li_Lighting	1.8	1.9	1.2	0.5	1.0	0.6	1.6
Me_Metals	1.3	0.8	0.2	1.2	2.9	1.0	1.5
Nu_Nucleon	0.1	1.8	0.7	5.3	3.1	1.2	0.1
Pa_Paper	13.9	4.9	0.4	1.7	0.5	1.0	1.8
Pe_Personal	1.3	1.1	2.1	1.3	1.6	0.4	2.1
Ph_Pharmac	0.4	0.4	1.0	1.1	0.6	1.4	1.4
Pr_Printing	0.5	1.2	1.2	1.3	1.0	2.4	0.2
Pu_PumpsEng	1.1	1.0	0.8	0.8	0.5	0.8	1.9
Se_Separate	1.3	1.3	1.3	0.7	1.0	1.3	0.9
Sh_Shaping	0.7	1.0	0.7	0.5	1.2	1.8	1.8
Te_Textiles	0.5	0.5	1.3	0.8	0.7	3.3	0.6
Tr_Transpor	1.8	1.3	1.2	0.8	1.0	0.7	1.3
We_Weapons	1.3	2.8	1.5	2.2	1.9	0.1	5.3
XX_Other	0.8	0.1	3.9	0.6	0.1	2.0	0.2

Estimates of ST parameters

Table A.10
1977 Data

	Domestic or Foreign	
	DO	FO
Destination Country	Effect	Effect
01_FR	1.0	1.0
02_GE	0.8	1.2
03_UK	1.1	0.9
04_US	0.8	1.2
05_JA	1.3	0.8

Estimates of DH parameters

Table A.11
1977 Data

	Domestic or Foreign	
	DO	FO
	Effect	Effect
Technology		
Ag_Agricult	1.4	0.7
Bu_Building	1.4	0.7
Ch_Chemist	0.7	1.4
Dr_Drilling	1.0	1.0
El_Electric	0.9	1.1
En_Engineer	0.9	1.1
Fd_Food	1.0	1.0
He_Health	1.0	1.0
In_Instrum	0.9	1.1
Li_Lighting	1.2	0.8
Me_Metals	0.9	1.1
Nu_Nucleon	0.8	1.2
Pa_Paper	0.9	1.1
Pe_Personal	1.3	0.8
Ph_Pharmac	0.7	1.4
Pr_Printing	1.1	0.9
Pu_PumpsEng	0.9	1.2
Se_Separate	0.9	1.1
Sh_Shaping	1.0	1.0
Te_Textiles	0.9	1.1
Tr_Transpor	1.1	0.9
We_Weapons	1.1	0.9
XX_Other	1.3	0.8

Estimates of TH parameters