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Do the New Global Information and Trade Links of the 1990s lead to Convergence or Divergence?[1]

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Abstract

There is evidence that some of the new links connecting different countries in the world have contributed to higher economic growth by allowing a greater level of international technology diffusion than before. With a relatively broad sample of about fifty countries, I examine how strong these effects in different parts of the world are. My findings suggest that the beneficial effects of higher technology diffusion on growth are not uniformly distributed over the world. Rather, they have been concentrated in the relatively rich countries. I also show that this asymmetry is important in explaining the recent trend towards income *divergence* in the world. This finding is in contrast to the widely-held belief, consistent with the prediction of many influential growth models, that a higher level of international technology diffusion leads to income *convergence* across countries. Given my relatively short sample period from 1983-95, it cannot be ruled out that international technology diffusion eventually leads to convergence. However, my results indicate that this would have to be far out in the future, which raises important welfare concerns.

Economic growth in a country can be derived from domestic or international sources. It can be due both to the domestic accumulation of inputs and to technological change. Moreover, growth can also be related to international technology spillovers–the increase in efficiency due to learning from technological investments abroad. While factor accumulation and domestic technological change have long been viewed as important for explaining differences in growth rates across countries, the significant increase in the level of economic integration of many countries recently has shifted the focus to international technology spillovers, because integration might be conducive to technology diffusion through a number of mechanisms.

However, once technology diffuses fully throughout the world, the global pool of technology means that technological change ceases to affect the ranking of countries in the world's income distribution. Today, differences in national technological trajectories still seem to matter, though. Many observers, for instance, have attributed the higher growth of the United States relative to other major countries between 1990-98 to a relatively high rate of technological change.[1] Thus, technology matters for *relative* income levels because technological change and the degree of technology spillovers are unevenly distributed in the world. If the extent to which countries benefit from international technology spillovers varies, then what explains these differences? Focusing on spillovers through trade and communication links, this paper gives an account of the effects of technology spillovers from G-7 countries on relative income levels of about 50 countries between the years 1983 and 1995. This will give some indication of whether a major technological innovations such as the internet will likely increase or decrease the variation of per capita income in the distribution of world income–that is, does it favor

[1]Consider Canada, France, Germany, Italy, Japan, the United Kingdom (U.K.), which together with the U.S. constitute the so-called G-7 countries. According to OECD (2000, Table 1), GDP per capita growth in the U.S. during 1990-98 was on average 2.0%, whereas it was 1.1% in Canada, 0.9% in France, 1.0% in Germany, 1.2% in Italy, 1.1% in Japan, and 1.7% in the United Kingdom. The U.S.'s relative performance is even better if one focuses on manufacturing, while it is slightly weakened if one looks at multi-factor productivity (OECD 2000, Tables 15 and 6, respectively).Overall, given that the U.S. has the highest income per capita, this tends to favor divergence, defined as an increase in the variation of GDP per capita for this period.

convergence or divergence across countries?

This is clearly of major interest from a policy point of view. This analysis also sheds new light on the extent to which differences in trade and communication links help explain differences in growth rates. This provides important clues for the design of economic policy that aims at increasing a country's benefits from international technology spillovers. This empirical analysis of the dynamic effects of international knowledge spillovers is also informative for the theory of growth, because spillovers are central in much of that recent literature (Aghion and Howitt 1992, Lucas 1988, and Romer 1990). If international knowledge spillovers in two-country models are sufficiently weak, such models can lead to all technical change becoming concentrated in one country. Eventually, this leads to income divergence between the countries (Feenstra 1996, Grossman and Helpman 1991, Ch. 8).[2] In most models, though, and especially when the model is subjected to estimation, there is the assumption of strong and asymmetric international spillovers–followers learn more from leaders than vice versa (Howitt 2000, Eaton and Kortum 1997, Lucas 1993). Typically, these assumptions give rise to a common long-run growth rate, even though temporarily, income levels might be diverging while technology spillovers are diffusing worldwide. We know very little so far as to whether these assumptions are empirically sound, and if so, what the time horizons are that are involved until convergence is achieved.

This work builds on a substantial body of literature that has shown that the relationship between R&D spending in one country and productivity effects in another can be used to estimate international knowledge spillovers (see Helpman 1997, Griliches 1979). In the recent empirical literature, Keller (2001a, 2001b) finds that there has been increasingly a common pool of technological knowledge among OECD countries in recent years. I contribute to this by asking whether this has also been the case for less developed countries, thereby starting to analyze the effects of greater international

[2] These effects extend also to the recent economic geography literature; see the integration of a spillover growth model with such an economic geography model in Baldwin and Forslid (2000).

technology diffusion on the world's income distribution. examining alternative channels for spillovers. A related paper is the analysis of North-South spillovers by Coe, Helpman, and Hoffmaister's (1997). These authors do not focus on world income distribution issues, though, as they study the productivity effects in a sample of only less developed countries.

Another literature tries to quantify the relative contribution of factor accumulation and technological change to growth (Solow 1957, Mankiw 1995, and Rodriguez-Clare and Klenow 1997). This paper contributes to this research agenda through providing an explicit account of the effects of differences in international knowledge spillovers to growth. Moreover, because divergence is less likely to happen according to growth models based on factor accumulation and decreasing returns to scale than according to the increasing returns growth models of knowledge accumulation mentioned earlier, this analysis provides also additional prima facie evidence on the empirical relevance of the two types of theories. The interest in communication flows as the means for international knowledge spillovers is broadly consistent with the work of Portes and Rey (1999), who find that bilateral communication flows help to account for differences in equity portfolio holdings across countries.

The remainder of the paper is as follows. I first provide an overview of major sample characteristics and introduce the variables that will be used. The main section two contains all estimation results. I conclude with a summary and discussion of the results in section three. A description of the data sources is provided in the appendix.

1 Data overview

1.1 Major sample characteristics

This study analyzes productivity dynamics in about fifty countries, the largest set for which I have been able to assemble all the relevant data. The countries are located in Latin America (thirteen countries), in Europe (fourteen countries), in Asia-Oceania (thirteen countries), and in Africa (ten countries). The countries are listed in Table 1. There are staggering differences in economic well-being among these countries. Using data from the Penn-World Tables (see Summers and Heston 1991), two such measures are computed: first, the Gross Domestic Product (GDP) per capita, which I also take as a proxy for labor productivity. Second, I construct a total factor productivity (TFP) index as $TFP = Y/\left(K^{0.33}L^{0.67}\right)$, where Y is GDP, K is the capital stock, and L is population. Over the sample period of 1983-95, GDP per capita relative to the U.S. ranges from a low of 2.7% to a high of 95.1%, which is by a factor of 35. The variation of TFP in the sample is lower, but with maximum TFP level being about 13 times higher than the lowest, it is still substantial.

It is well-known that there is substantial variation in these measures by continent; Table 2 summarizes some of these differences. For instance, the average relative labor productivity level in Africa has been 8.7%, compared to 18.1% in Latin America, 34.7% in Asia-Oceania, and 63.1% in Europe. The capital-labor ratio in Europe was on average about 18 times higher than in Africa and about 4 times higher than in Latin America. As a measure of human capital, countries in Latin America had on average only about two thirds of the secondary years of schooling in the total population of the countries in Asia-Oceania, but twice as many as the African countries (source: Barro and Lee 1995).

1.2 Technology spillovers from the G-7

The focus in this paper is on the effects of technology spillovers from the G-7 countries, that is, from Canada, France, Germany, Italy, Japan, the U.K., and the United States. These countries are the major producers of new technology at the world level, accounting for more than 90% of the world's spending on research and development (R&D), see OECD (1999). While some of the countries tries in this sample conduct a significant amount of R&D on their own, thereby generating growth domestically, most countries adopt technology developed elsewhere rather than creating new technology at the world level. And even for countries like the Netherlands that conducts nonnegligible amounts of R&D domestically, some recent evidence suggests that foreign sources of technology are of dominant importance for such countries (Keller 2001a).

How might the effects of technology spillovers on productivity have changed over time? On hypothesis is that as new links between countries are forged that might serve as channels for technology spillovers, this has intensified the effects from foreign technology spillovers. I focus here on trade and communication links as channels for spillovers. The former is measured by manufacturing imports (source: Feenstra et al. 1997), while communication links are proxied by telephone call traffic (in minutes; source: ITU 1996). Table 2 shows summary statistics of incoming telephone traffic and imports by continent. For instance, the median of incoming telephone calls from the G-7 countries, relative to country's GDP, is 2.16 in Europe, while it is only 0.73 in Africa.[3] The median import share (all trade, not just G-7) in Latin America was 10.9%, compared to 43.6% in Europe, 15.0% in Asia-Oceania, and 10.2% in Africa.

Of course, neither trade nor telecommunication are new at the beginning of my sample period in 1983. However, on average for these fifty countries, both the import share as well as telephone call penetration has reached by 1983 unprecedented levels. Moreover, the growth rates of imports and telephone call volume during the period of 1983-95 has been high by historical standards as well. For international trade, this can be seen from Table 3, which reports statistics on the sum of imports and exports divided by GDP for the 50 countries of the sample between 1952 and 1992 (from Summers and Heston 1991). By 1983, the openness measure had reached about 59%, more or less steadily increasing in the post-World War II era. On the right of Table 3, the average annual growth rates of the openness measure indicate that although the level of trade in 1983 was at its historic high for

[3] This level difference surely depends on a number of factors that are unrelated to technology diffusion (including international migration and the associated cross-country family relations, and others). The empirical analysis below relies therefore on changes in these variables.

these 50 countries, nevertheless the growth of trade between 1983 and 1992 was substantially higher than in other decades since World War II.

In the regression analysis below, I employ two simple measures of technology spillover inflows from the G-7 countries. The imports spillover measure S^I is given by

$$S^I_{ct} = \sum_{g \epsilon G7} M_{cgt} \times R_{gt}, \forall c, t, \tag{1}$$

where $c, c = 1, ..., 50$ indexes the spillover receiving country, g, $g = 1, ..., 7$ indexes a G-7 country, and $t, t = 1983, ..., 1995$ indexes the year; M_{cgt} are country c's manufacturing imports from g in year t, and R_{gt} is G-7 country g's cumulative R&D stock in year t. The telephone calls based spillover measure S^P is constructed analogously, with

$$S^P_{ct} = \sum_{g \epsilon G7} P_{cgt} \times R_{gt}, \forall c, t, \tag{2}$$

where P_{cg} is the telephone call traffic incoming in country c from G-7 country g. Note that both measures are constructed as weighted sums of the G-7 countries R&D stocks. This means that they are likely to be correlated. Further, the G-7 R&D stocks are the same for all 50 sample countries. Thus, there two reasons why the variables S^I and S^P will vary across countries. First, they will pick up different levels of imports and incoming calls (M and P, respectively), across countries. Second, for a given total level of imports and incoming calls, the measures reflect the composition of a country's trade or telephone traffic, that is, whether it comes from relatively high- or low-R&D G-7 countries. Implicit in the definition of the measures S^I and S^P are a number of restrictions that might not hold. As an example, it is assumed that the magnitude of spillover inflows are independent of the bilateral geographic distance between the receiving and each of the G-7 countries. In this respect, the results in this paper should be considered as a first step.

1.3 Descriptive statistics

The empirical analysis will rely primarily on relating changes in productivity to changes in S^I and S^P and other variables over two subperiod of equal length: the years 1983-89 and the years 1989-95. Table 4 shows some key summary statistics for these subperiods. Over the six-year period of 1983-89, G-7 R&D (that is, $\sum_{g \epsilon G7} R_g$) grew by 34.15%, or close to 6% per year. By contrast, during the later period of 1989-95, growth was only 24.55%, or about 4% per year. It is well-established empirically that R&D investments trigger productivity growth; for instance, U.S. labor productivity growth during 1983-89 was 16.8%, whereas it was only 4.6% during 1989-95. Thus, this difference in G-7 R&D stock growth between the two subperiods suggests that the rate of technical change in the G-7 countries, including the U.S. was relatively high during 1983-89, and lower thereafter.

The sample as a whole fell further behind the U.S. during the early years of the sample period: relative to the U.S., labor productivity grew on average by about -9% during the period of 1983-89. There are large differences by continent: the European countries have kept up with the U.S. relatively well, but most countries in Latin America and in particular Africa have been falling behind substantially. The figures on TFP growth confirm the basic findings. One interpretation of this is that during the period of 1983-89, high rates of technical change and growth in the word's leading countries has moved them further ahead of the sample mean. The degree to which the fifty countries of the sample have kept up with the frontier appears to be, with Europe doing relatively best and Africa relatively worst, broadly correlated with the level of productivity. This means that during 1983-89, the variation of productivity levels among the fifty countries has gone up. This is confirmed by the standard deviation of initial relative TFP, which was 22.35% in 1983 and 23.62% in 1989 (see Table 4). Taken together, this means that during 1983-89 there has been divergence of productivity both between the frontier (the U.S., for short) and the average country of the sample and between the richer and the poorer countries of the sample.

By contrast, during the years of 1989-95, the average country in the sample has not lost further ground relative to the U.S., as the growth of relative labor productivity of 3.69% indicates. The extent of catch-up on average is small, however. Moreover, the productivity performance varies qualitatively across continents, with the average African country falling further behind (growth of relative labor productivity of -13.57%), while the average Asian-Oceanian country has caught up rapidly (with a rate of 15.88%). Given that the African countries are towards the lower end of the productivity ranking, these findings suggest a bifurcation of the sample during the years 1989-95: At a time when productivity growth at the world's frontier has slowed down, the majority of the sample countries which are at the higher end of the productivity spectrum catch to some extent up with the frontier, while the low productivity countries fall behind further. If this interpretation is broadly valid, the variation of productivity levels across countries is likely to have increased further. This is confirmed by the standard deviation of relative TFP levels of 24.89% in 1995, versus a value of 23.62% in 1989.

In section two, I will see whether these basic interpretations hold up when simple econometric techniques are employed. It will also be investigated whether the productivity dynamics are significantly related to trade and communication links across countries. As a preview to that, Table 4 summarizes the growth of imports and of incoming telephone calls by continent and by subperiod. The growth of imports from the G-7 countries for the average country has been about 5.5% a year during both 1983-89 and 1989-95, although the import dynamics vary strongly by continent: growth of imports increased substantially over time in Latin America and in Asia-Oceania, whereas it fell in both Africa and Europe. Also telephone call volume grew at roughly the same rates on average during the two subperiods (about 15% per year). Quite different from the case of imports, though, here Africa is the only continent for which *the growth* of the volume of incoming calls increased over time. It is clear, in any case, that these differences of growth rates of imports and call volume need to be considered in conjunction with differences in the levels of trade and call volume to obtain a complete picture (see Table 2). I now turn to the estimation results.

2 Estimation results

The estimation framework I use is simple. Let y_{ct} be country c's labor productivity relative to the U.S. in year t. It is assumed that y_{ct} is a log-linear function of country c's capital stock relative to the U.S. (denoted k) and of other factors X_{ct} that may include the imports- and phone-call based spillover measures defined in equations (1,2). Relative labor productivity also depends on an intercept (α_t), on unobserved country-specific fixed factors (α_c), and on an error term, $\ln \varepsilon_{ct}$.

$$\ln y_{ct} = \alpha_t + \alpha_c + \beta \ln k_{ct} + \gamma' \ln \mathbf{X}_{ct} + \ln \varepsilon_{ct}. \tag{3}$$

I estimate the parameters γ' that are of key interest by taking long (six-year) differences. This leads to

$$\Delta y_{ct} = \alpha_0 + \beta \Delta k_{ct} + \gamma' \Delta X_{ct} + \Delta \varepsilon_{ct}, \tag{4}$$

where for any variable v, Δv is defined as its six-year log difference; α_0 is a constant, and I assume that $\Delta \varepsilon_{ct}$ has mean zero. The TFP growth specifications are analogous to equation (4), without the capital growth term on the right hand side. As noted above, productivity dynamics in the sample in the two six-year periods of 1983-89 and 1989-95 seem to be quite different, so I present estimates for each subperiod separately. Table 5a reports results with labor productivity growth as the dependent variable for 1983-89.

2.1 Results for 1983-89

Specification 5.1a includes the capital growth variable Δk and the initial log relative labor productivity (that is, $\ln y_{ct-6}$). The initial productivity level picks up a catch-up effect, if present. A negative coefficient on initial productivity means that countries with initially lower productivity grow subsequently faster, all else equal. Here, I estimate a coefficient of 0.048, significantly larger than zero, which suggests that conditional on capital growth (with a $\beta = 0.566$), there is higher growth for the initially high-productivity countries. This is consistent with divergence of productivity levels. In specification 5.2a, the imports-based spillover variable S^T is introduced along with capital and initial productivity. This lowers the coefficient on capital growth, as one would expect if capital growth is positively correlated with spillover growth. The spillover variable S^T has a coefficient of about 0.2, significantly larger than zero at standard levels. Also note that the R^2 goes up substantially, from 0.335 in specification 5.1a to 0.563 in specification 5.2a. The catch-up coefficient on initial productivity turns insignificant, which suggests that the spillover variable explains in part why there is divergence of productivity in the raw data.

In contrast to the imports-based spillover variable, the telephone-call based variable S^P does not appear to have a strong effect on productivity growth significantly, see specification 5.3a, where the coefficient on S^P is positive, but not significant at standard levels. Column 5.4a shows that the effect of the trade spillover variable S^T is robust to the inclusion of the level of human capital (h, defined as years of secondary schooling in total population) in the initial year of the subperiod. The coefficient on human capital itself is positive, but not larger than zero at standard significance levels.[4] Adding human capital in the regression with S^P does not change much either regarding the significance of S^P or human capital, see 5.5a.

[4] I have also considered changes in human capital as a factor accounting for productivity growth; it does very poorly. This is consistent with the findings of many others in the growth literature.

It is sometimes argued that human capital is crucial in adopting and implementing foreign technology (e.g. Keller 1996). To test for this, I have interacted the spillover variables S^T and S^P with human capital. The coefficient on $\ln h \times \Delta S^T$ in specification 5.6a is positive and quite large, but relatively imprecisely estimated. This is even more so the case in the analogous specification with $\ln h \times \Delta S^P$ (see 5.7a). Specification 5.8a compares the performance of the two spillover variables directly. The results confirm that the imports-based spillover variable performs much better than the phone call-based variable. The final column of Table 5a presents the preferred specification for this period, with capital, initial productivity, imports-based spillovers S^T, and their interaction with human capital as regressors. These variables account for about 60% of the variation in labor productivity growth. In addition, there is evidence in favor of imports-based foreign technology spillovers, as both ΔS^T and its interaction with human capital are estimated to have a positive effect on productivity growth.

Table 5b presents the analogous regressions using TFP growth as a dependent variable. The results are broadly similar. These regressions underline the magnitude to which the imports-based spillover variable helps accounting for productivity growth: including the ΔS^T variable raises the R^2 substantially, from about 5% to about 40% (see 5.1b and 5.2b). One difference is that in the TFP specifications, the effect from the $\ln h \times \Delta S^T$ variable is not only relatively large but also fairly precisely estimated (see 5.6b). Also here though, there is no statistically significant effect from the phone-based spillover variable ΔS^P. Noteworthy is also that in the preferred specification 5.9b, the catch-up variable $\ln y_{ct-6}$ enters with a significantly negative parameter. This is consistent with convergence conditional on differences in TFP growth related to foreign technology spillovers. Or, put in another way, this suggests that differences in benefits derived from foreign spillovers across countries are important in explaining the trend towards divergence that is evident in the raw data. I now turn to results for the later subperiod.

2.2 Results for 1989-95

Table 6a shows the results for this period with labor productivity as the dependent variable. As the first specification in Table 6a shows, on average, controlling for capital investments, there is a positive relationship between productivity in 1989 and subsequent growth: the coefficient on $\ln y_{ct-1}$ is equal to 0.04. However, recall from Table 4 that countries in different continents had qualitatively different growth experiences during this period. It appears, therefore, that specification 6.1a masks a substantial amount of heterogeneity. To investigate this further, Figure 1 shows the relationship of labor productivity growth versus initial productivity. The line visualizes it nonparametrically by using a locally weighted smoothed scatter plot. Figure 1 confirms that there is a broad positive relationship between initial productivity and subsequent growth. However, the range for which there is a clear positive relationship is confined to the low end of initial productivity. By contrast, for the countries with higher initial productivity, there appears to be a negative relationship between initial productivity and subsequent growth. This is clearly picked up by the downward sloping segment of the smoothed line.

A simple parametric approach that incorporates this fact into the analysis is to allow for a piece-wise linear relationship between initial productivity and growth. Splitting the sample in two at the median initial productivity level, the triangles in Figure 2 show the relationship of fitted productivity growth and initial productivity for the two subsamples: a positive relationship if initial productivity is below the median, and a negative relationship above the median. Specification 6.2a shows how this translates into regression analysis. The coefficient for the subsample with relatively low initial productivity is estimated to be 0.177, significantly larger than zero at standard levels; and for the subsample with relatively high initial productivity, I estimate a coefficient of -0.067, also different from zero at standard significance levels. The spline regression results also in a big improvement in terms of explained variation, as the increase in the R^2 from 0.377 to 0.528 indicates. The findings reflect the relatively low productivity growth in the poorest countries, primarily in Africa, and document well the overall trend towards further divergence among these fifty countries. At the same time, so far the trend towards divergence is just data; it has not been related to any particular factor(s).

In specification 6.3a, I add the imports-based spillover variable to the capital and initial productivity variables already included. A coefficient of 0.041 is estimated, much smaller than the coefficient of about 0.2 in the earlier period; moreover, at standard levels, the coefficient on ΔS^T is not significantly different from zero. It might be, however, that the impact of foreign spillovers is different for low-productivity and high-productivity countries. Therefore, in specification 6.4a I have included the interaction of low-productivity and ΔS^T as well as that of high-productivity and ΔS^T as separate regressors. The results indicate that for countries with relatively low initial productivity, there is no benefit from import-based foreign spillovers, as the coefficient is equal to -0.010, not significantly different from zero. By contrast, the corresponding coefficient for high-productivity countries is equal to a precisely estimated 0.181. This suggests that imports-related spillovers from the G-7 countries explain in part the trend towards divergence among these 50 countries, as they benefit the relatively high-productivity countries, but do not significantly affect productivity growth in the low-productivity countries.

It is interesting to note that the introduction of the spillover variable S^T interacted with initial productivity leads to a stronger trend towards convergence among the countries with relatively high initial productivity (compare the coefficient of -0.067 on high initial productivity in 6.2a with the value of -0.128 in 6.4a). This results from the fact that even within the high initial-productivity sample, the countries that benefit most from foreign spillovers are those with relatively high productivity. Thus, controlling for this effect, the trend towards convergence becomes stronger.[5] Another observations

[5] I have also experimented with introducing ΔS^T in addition to its interactions with the low initial productivity and

is that the trend towards divergence *among* the relatively low-productivity countries has apparently nothing to do with differential access to foreign technology spillovers. This is consistent with the hypothesis that none of these countries benefit from foreign spillover to a significant extent. I add to these variables the human capital variable in specification 6.5a, without changing much.

Moving to the phone-call based spillover variable S^P, specification 6.6a assumes a common effect of spillovers in both low- and high-productivity countries, analogous to specification 6.3a. Also here, the spillover variable is not significantly different from zero. That changes once one allows for a differential effect in low- and high initial productivity countries, see 6.7a. Conditional on high initial productivity, more phone call-related spillovers are associated with higher productivity growth; the coefficient of 0.172 is fairly precisely estimated and comparable in magnitude to the imports-related spillover coefficient of specification 6.4a. At the same time, for low initial productivity countries, no significant phone call-related spillover effect is estimated, which parallels the findings for the S^T spillover variable. The positive effect of S^P for high initial-productivity countries is robust to the inclusion of the human capital variable, see 6.8a. Rather, the main effect of the human capital variable is to reduce the size of coefficient on initial labor productivity variable for the low productivity subsample; the estimate of 0.080 is not statistically different from zero anymore. This suggests that low human capital levels are in part what is driving the particularly low productivity growth in countries with the lowest levels of initial labor productivity. Finally, specification 6.9a introduces the interacted S^T and S^P variables together to see which has the stronger effect. The results are fairly poor in that few coefficients are precisely estimated; nevertheless it becomes clear that the effect from imports-related spillovers dominates that via phone-call based spillovers according to these estimates.

Table 6b shows the corresponding results with TFP growth as the dependent variable. Among the few differences is the result that human capital is positively related to TFP growth, whereas no

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high initial productivity variables, but the ΔS^T variable by itself has no significant effect.

such effect could be detected in the corresponding labor productivity regressions (compare 6.5b and 6.8b with 6.5a and 6.8a, respectively). Overall, however, the TFP growth results are strikingly similar to those obtained with labor productivity growth as the dependent variable. First, there is a trend towards divergence among low initial-productivity countries, and towards convergence among high initial productivity countries. Second, the effect of imports- and phone-call related spillovers is not uniform across countries with different productivity levels. Rather, high productivity countries benefit from these spillovers while low productivity countries do not. Third, while I estimate that there are both substantial spillovers related to imports and related to incoming call traffic for high productivity countries, the effects related to trade appear to be stronger. The following discussion concludes the paper.

3 Summary and discussion

The preceding empirical analysis suggests in my view that, by and large, the new trade and communications links of the 1990's have contributed to divergence rather than convergence of productivity levels across countries. The reason for this lies primarily in the fact that the new trade and communications links have developed non-uniformly across different parts of the world. The evidence presented above shows that the new links are positively related to growth in productivity, but as long as not all countries in the world are connected to them, this seems to mean more inequality in terms of per capita income levels, not less.

This statement needs to be qualified for a number of reasons. Most importantly, for an analysis of economic growth, my sample period of twelve year is relatively short. It might thus be that over a longer time horizon, say thirty or fifty years, the new trade and communication links are not only raising the average income per capita in the world, but they also lead to a convergence of income per capita across countries. Indeed, the time patterns in the results presented above are very suggestive that the length of the time horizon matters for what one concludes.

It appears that during the period of 1983-89, when the technical change and growth among the world's leader countries was relatively high, only the countries at the very top in terms of productivity in the sample could more or less follow. Once the rate of growth among the leader countries had slowed by 1989-95, another set of countries started to benefit from technological innovations from the technology frontier. Overall, this effect was strong enough so that the average sample country's productivity relative to the U.S. increased during this period, thereby reverting to the catch-up effect that is expected if eventually income per capita is converging. The findings suggest that the diffusion of new technologies from the technology frontier to other countries is a process that takes real time and that will reach countries with relatively high productivity levels first.

But will it eventually reach all countries, even those that during the period of 1983-95 have lost further ground relative to the richer countries? This question will have to be answered by future analyses that cover longer time spans than the present one. In addition, posing this question seems to suggest that the diffusion of technology largely depends on time and initial productivity, things that might be considered as exogenous factors. Another question, one that it is more fruitful to pose is: what are the major determinants of successful technology diffusion for the type of technologies that are being developed today? To answer this question requires to carefully examine cross-country and cross-industry variation in the speed and extent of the diffusion of new technologies from abroad.

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A Data on Telecommunication

Data on telecommunication has been provided by STARS database by the International Telecommunication Union. This data represents the total inward calls originating from the G7 countries. The data is in part estimated because of missing values in the original source. The missing data is interpolated using exponential growth. The telephone data for inward calls originating in Japan is interpolated by using average worldwide growth in call volumes from Japan starting from the initial value.

B Data on labor inputs, physical capital and value added.

The TFP index uses data on labor and physical capital. Population, real GDP per worker and real capital per worker for the years 1980-92 are based on Summers and Heston database. These four variables are used to compute the real capital stock from1980-92. We use real GDP and population for the years 1993-95 and average growth rate of the capital stock for 1990-95 from Levin, Loayaza, Beck (2001) to construct the real capital stocks of 1993-95.

C Data on Human Capital

The human capital variable represents the average years of total secondary schooling, and is taken from Levine, Loayaza, Beck (www.worldbank.org/ research/ growth/ llbdata.htm). The original source is due to Barro and Lee . The data is only available on a five yearly basis, therefore we use 1980 value for 1980-84, the 1985 for 1985-89 and 1990 for 1990-95.

D Data on Import Flows

The data on import flows for 1983-92 comes from the NBER World Trade Database, see Feenstra et al. (1997). The bilateral trade flows represent the import of manufactures from the G7 countries. The value for 1995 is obtained from UN COMTRADE database, and values for 1993-94 are interpolated.

E Data on R&D

The raw data on R&D expenditures comes from "All Business R&D" from OECD ANBERD database. The construction of the cumulative R&D stocks is based on total business enterprise expenditure on R&D (I), in constant 1985 US \$. We use the perpetual inventory method to construct technology stocks, assuming that

$$R_t = (1-\delta)R_{t-1} + I_{t-1}, \text{ for } t = 2, ..., 12$$

and

$$R_1 = \frac{I_1}{\lambda + \delta + 0.1}$$

The rate of depreciation of the knowledge stock, δ, is set at 0.1 and λ is the average annual growth rate over 1983-95.

Table 1

List of sample countries by continent

Latin America

Number	Name
1	Argentina
2	Bolivia
3	Chile
4	Colombia
5	Dominican Republic
6	Ecuador
7	Guatemala
8	Honduras
9	Jamaica
10	Mexico
11	Panama
12	Paraguay
13	Peru

Europe

Number	Name
1	Austria
2	Belgium
3	Denmark
4	Finland
5	Greece
6	Iceland
7	Ireland
8	The Netherlands
9	Norway
10	Portugal
11	Spain
12	Sweden
13	Switzerland
14	Turkey

Asia and Oceania

Number	Name
1	Australia
2	Hong Kong
3	India
4	Iran
5	Israel
6	Republic of Korea
7	Nepal
8	Nea Zealand
9	Philippines
10	Sri Lanka
11	Syria
12	Taiwan
13	Thailand

Africa

Number	Name
1	Ivory Coast
2	Kenya
3	Madagascar
4	Malawi
5	Mauritius
6	Morocco
7	Nigeria
8	Sierra Leone
9	Zambia
10	Zimbabwe

Table 2

Country characteristics by continent
Period 1983-95

	Latin America	Europe	Asia & Oceania	Africa
Labor Productivity*	0.181	0.631	0.347	0.087
	[0.081]	[0.204]	[0.265]	[0.077]
Total Factor Productivity*	0.329	0.66	0.467	0.242
	[0.111]	[0.142]	[0.248]	[0.147]
Capital-Labor Ratio	2869	14226	6415	756
	[1599]	[8166]	[5066]	[677]
Years of second. schooling**	1.322	2.231	1.938	0.628
	[0.400]	[0.844]	[1.113]	[0.402]
Incoming calls to GDP***	1.677	2.165	0.609	0.735
	[6.418]	[2.889]	[1.135]	[0.608]
Imports to GDP****	0.11	0.436	0.15	0.102
	[0.237]	[0.214]	[0.280]	[0.048]
No. of countries	13	14	13	10

*Average, relative to the United States

** Average number of years of secondary schooling in the total population

***Median of incoming phone calls from G-7 countries to GDP; in minutes/$

****Median of manufacturing imports from the world over GDP

Numbers in hard brackets are standard deviations

Table 3

The intensity of trade over time in the fifty sample countries

Year	Level of Openness*	Period	Growth of Openness**
1952	45.30	1950-83	0.0083
1962	51.04	1960-83	0.0083
1972	52.12	1970-83	0.0081
1982	59.34	1983-92	0.0185
1983	58.91	1983-90	0.0221

* Average of Imports + Exports over GDP (Openness from Summers & Heston 1991), in percent

Note: Because of missing data, this average is calculated over a varying number of countries

** Annual growth of openness, averaged across all countries w/ available

*** Average annual growth of openness across all fifty countries (years 1991 and 1992 missing for some)

Table 4

Summary statistics

	1983-89		1989-95		1995-	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Growth of G7 R&D	0.3415	0.0000	0.2455	0.0000		
Growth of rel. labor productiv.	-0.0933	0.1841	0.0369	0.1512		
Lat. Am.	-0.1736	0.1342	0.0521	0.0974		
Europe	-0.0008	0.0411	0.0328	0.1116		
Asia-Oc.	-0.0283	0.2251	0.1588	0.1210		
Africa	-0.2027	0.2205	-0.1357	0.1394		
Growth of rel. TFP	-0.0583	0.1522	0.0317	0.1252		
Initial level of rel. TFP	0.4409	0.2235	0.4316	0.2362	0.4499	0.2489
Growth of imports from G7	0.3357	0.4543	0.3273	0.4760		
Lat. Am.	0.2318	0.4440	0.4265	0.5454		
Europe	0.5571	0.2067	0.1894	0.1769		
Asia-Oc.	0.2464	0.5654	0.5922	0.4884		
Africa	0.2768	0.5154	0.0469	0.4915		
Growth of phone calls fr. G7	0.9085	0.3573	0.8364	0.2548		
Lat. Am.	1.0365	0.2200	0.9204	0.2017		
Europe	0.6347	0.1460	0.5963	0.1282		
Asia-Oc.	1.0917	0.3679	0.9897	0.2617		
Africa	0.7965	0.4976	0.8795	0.2268		

Table 5a

Labor productivity growth, 1983-89

Variable	5.1a	5.2a	5.3a	5.4a	5.5a	5.6a	5.7a	5.8a	5.9a
d lnK	0.566**	0.455**	0.543**	0.501**	0.578**	0.401**	0.554**	0.455**	0.441**
	[0.258]	[0.171]	[0.230]	[0.144]	[0.214]	[0.166]	[0.211]	[0.173]	[0.151]
y0	0.048**	0.032	0.067**	-0.006	0.023	-0.02	0.032	0.032	-0.026
	[0.023]	[0.023]	[0.029]	[0.029]	[0.038]	[0.030]	[0.042]	[0.022]	[0.029]
d lnS^T		0.198**		0.203**		0.185**		0.198**	0.193**
		[0.053]		[0.056]		[0.066]		[0.048]	[0.056]
d lnS^P			0.136		0.118		0.119	-0.001	
			[0.106]		[0.130]		[0.132]	[0.073]	
h0				0.059	0.056	-0.082	-0.028		
				[0.044]	[0.055]	[0.106]	[0.184]		
d lnS^T * h0						0.21			0.116**
						[0.140]			[0.057]
d lnS^P *h0							0.051		
							[0.102]		
n	49	49	49	45	45	45	45	49	45
R sq	0.335	0.563	0.391	0.559	0.365	0.598	0.369	0.563	0.588

d lnK: growth rate of capital stock; y0: initial log level of labor productivity; d lnS^T: growth rate of imports-based spillovers (eq.1)
d lnS^P: growth rate of phone call based spillovers (eq. 2); h0: log of total secondary yrs of schooling in initial year
n: number of observations in regression;
Huber-White corrected (heteroskedasticity-consistent) standard errors in hard brackets
** indicates significance at a 5% level; * significant at a 10% level

Table 5b

Total factor productivity growth, 1983-89

Variable	5.1b	5.2b	5.3b	5.4b	5.5b	5.6b	5.7b	5.8b	5.9b
y0	0.059**	0.008	0.081**	-0.065	0.006	-0.085*	0.02	-0.001	-0.095**
	[0.028]	[0.025]	[0.033]	[0.047]	[0.062]	[0.045]	[0.060]	[0.030]	[0.047]
d lnS^T		0.200**		0.210**		0.187**		0.213**	0.201**
		[0.043]		[0.039]		[0.050]		[0.039]	[0.039]
d lnS^P			0.118		0.099		0.098	-0.032	
			[0.097]		[0.108]		[0.114]	[0.079]	
h0				0.076	0.064	-0.103	-0.078		
				[0.045]	[0.054]	[0.083]	[0.161]		
d lnS^T * h0						0.247**			0.131**
						[0.106]			[0.050]
d lnS^P *h0							0.089		
							[0.092]		
n	49	49	49	45	45	45	45	49	45
R sq	0.045	0.389	0.11	0.415	0.104	0.509	0.123	0.392	0.484

y0: initial log level of TFP; d lnS^T: growth rate of imports-based spillovers (eq.1)
d lnS^P: growth rate of phone call based spillovers (eq. 2); h0: log of total secondary yrs of schooling in initial year
n: number of observations in regression;
Huber-White corrected (heteroskedasticity-consistent) standard errors in hard brackets
** indicates significance at a 5% level; * significant at a 10% level

Table 6a

Labor productivity growth, 1989-95

Variable	6.1a	6.2a	6.3a	6.4a	6.5a	6.6a	6.7a	6.8a	6.9a
d lnK	0.429**	0.324**	0.300**	0.269**	0.263**	0.313**	0.306**	0.307**	0.280**
	[0.093]	[0.086]	[0.089]	[0.089]	[0.087]	[0.094]	[0.096]	[0.098]	[0.095]
y0	0.040**								
	[0.018]								
low y0		0.177**	0.160**	0.167**	0.129*	0.182**	0.141*	0.080	0.134
		[0.044]	[0.048]	[0.045]	[0.065]	[0.046]	[0.076]	[0.109]	[0.080]
high y0		-0.067**	-0.051	-0.128**	-0.144**	-0.063**	-0.228**	-0.261**	-0.094
		[0.031]	[0.035]	[0.036]	[0.047]	[0.031]	[0.086]	[0.098]	[0.110]
d lnS^T			0.041						
			[0.037]						
low y0*d lnS^T				-0.010	-0.012				-0.010
				[0.012]	[0.018]				[0.012]
high y0*d lnS^T				0.181**	0.169**				0.251**
				[0.044]	[0.047]				[0.105]
h0					0.038			0.046	
					[0.042]			[0.043]	
d lnS^P						0.031			
						[0.079]			
low y0*d lnS^P							0.022	0.036	0.020
							[0.046]	[0.059]	[0.050]
high y0*d lnS^P							0.172**	0.177*	-0.070
							[0.076]	[0.088]	[0.133]
n	49	49	49	49	45	49	49	45	49
R sq	0.377	0.528	0.541	0.592	0.580	0.531	0.561	0.553	0.601

d lnK: growth rate of capital stock; y0: initial log level of labor productivity; d lnS^T: growth rate of imports-based spillovers (eq.1)
d lnS^P: growth rate of phone call based spillovers (eq. 2); h0: log of total secondary yrs of schooling in initial year
low y0: lower half of the observations in terms of y0 (spline); high y0: higher half of the sample in terms of y0
n: number of observations in regression;
Huber-White corrected (heteroskedasticity-consistent) standard errors in hard brackets
** indicates significance at a 5% level; * significant at a 10% level
All regressions have a constant (not reported)

Table 6b

TFP growth, 1989-95

Variable	6.1b	6.2b	6.3b	6.4b	6.5b	6.6b	6.7b	6.8b	6.9b
y0	0.024 [0.027]								
low y0		0.127** [0.059]	0.073 [0.069]	0.099 [0.062]	0.014 [0.091]	0.126** [0.061]	0.053 [0.131]	-0.026 [0.160]	0.029 [0.141]
high y0		-0.075 [0.070]	-0.022 [0.077]	-0.149* [0.083]	-0.232** [0.088]	-0.079 [0.064]	-0.400** [0.137]	-0.506** [0.142]	-0.058 [0.216]
d lnS^T			0.082* [0.045]						
low y0*d lnS^T				-0.038 [0.026]	-0.041 [0.029]				-0.037 [0.024]
high y0*d lnS^T				0.253** [0.070]	0.230** [0.047]				0.474* [0.218]
h0					0.087* [0.045]			0.091** [0.040]	
d lnS^P						-0.015 [0.096]			
low y0*d lnS^P							0.063 [0.082]	0.069 [0.084]	0.052 [0.084]
high y0*d lnS^P							0.310** [0.123]	0.310** [0.124]	-0.207 [0.261]
n	49	49	49	49	45	49	49	45	49
R sq	0.013	0.071	0.160	0.205	0.322	0.072	0.144	0.553	0.240

y0: initial log level of labor productivity; d lnS^T: growth rate of imports-based spillovers (eq.1)
d lnS^P: growth rate of phone call based spillovers (eq. 2); h0: log of total secondary yrs of schooling in initial year
low y0: lower half of the observations in terms of y0 (spline); high y0: higher half of the sample in terms of y0
n: number of observations in regression;
Huber-White corrected (heteroskedasticity-consistent) standard errors in hard brackets
** indicates significance at a 5% level; * significant at a 10% level
All regressions have a constant (not reported)

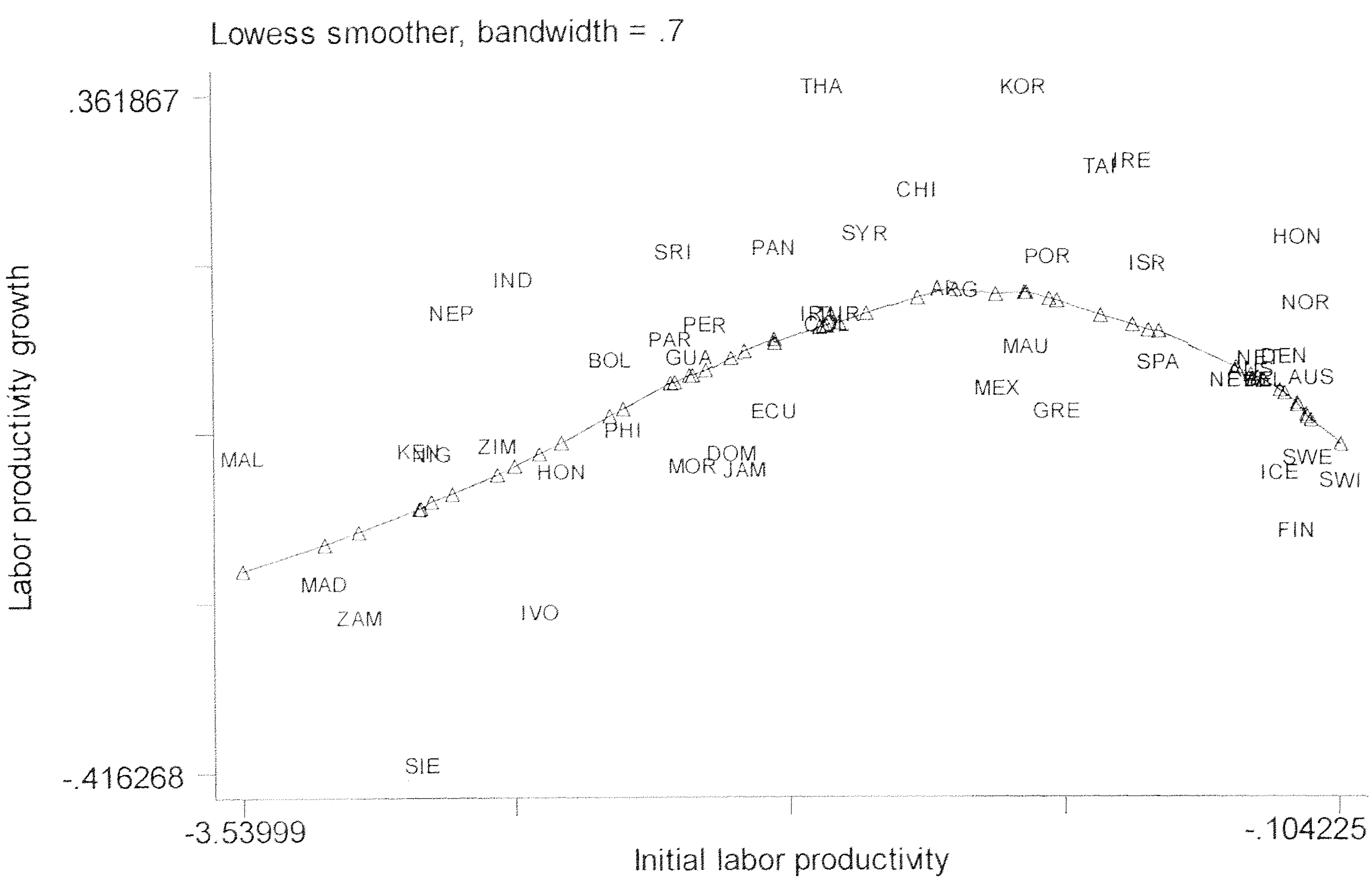

Figure 1. Non-linear labor productivity dynamics, 1989-95

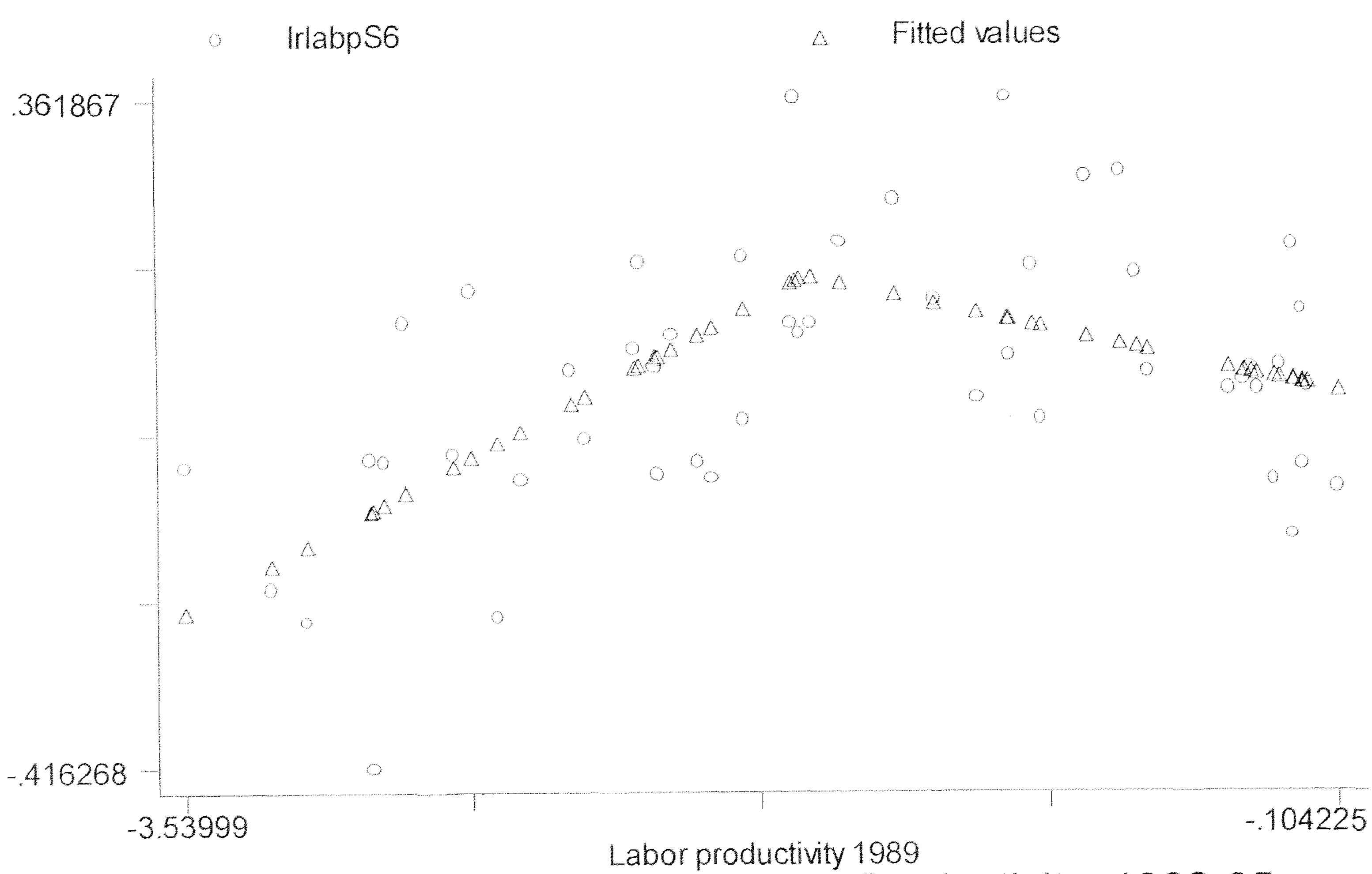

Figure 2. Spline based on Initial Labor Productivity, 1989-95