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INTERNATIONAL TRADE AND U.S. PRODUCTIVITY

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Abstract

This paper examines the effect of international trade on U.S. productivity. We argue that trade can affect domestic productivity through economies-of-scale effects, competition effects, reallocation effects, and spillover effects. We then estimate the net impact of these effects. The results of both panel and time-series regressions of manufacturing data indicate that (1) a decrease in the import price has a positive competition effect on manufacturing productivity growth after one to two years, and this impact is bigger when import penetration is bigger; and (2) exporting activity by itself does not seem to promote productivity. Our results suggest that the competition effect and/or the reallocation effect are the most powerful among the four channels. The simulation results indicate that import competition accounted for about 32 percent of labor productivity growth in manufacturing during 1996-2001.

1. Introduction

The strong revival of US productivity growth since the end of 1995 has generated much debate, and has spurred voluminous research, on what caused the productivity acceleration and whether that acceleration is sustainable.[1] The intensity of the debate underscores the importance of productivity growth in the overall economic performance as well as the inadequacy of our understanding of what drives productivity growth.

Against this background, and in light of continuing controversy over globalization, whether international trade helps promote productivity growth is an area of research that is gaining in importance. Some researchers have indeed found some, if not overwhelming, support for the view that increasing openness has a positive impact on productivity. For example, Mann (1998) finds that increases in the import share of consumption are associated with increases in trend productivity growth in the manufacturing sector. Bernard and Jensen (1999) find that, mainly through reallocation of resources from less efficient to more efficient plants, manufacturing exporters within the same industry do grow faster than non-exporters. Lawrence (2000) finds that trade with developing countries boost total-factor productivity (TFP) growth in manufacturing industries with a relatively large share of imports from developing countries. Coe and Helpman (1995) find that a country's TFP depends on not only its own R&D capital stock but also on the R&D stock of its trade partners. Most recently Keller and Yeaple (2003) find that there is some evidence for imports-related spillover of technology. Nevertheless, neither theory nor empirical evidence on this subject is definitive so far. In one of his papers prompted by the recent productivity debate, Gordon (2000b) even argues that openness to trade has an adverse effect on productivity.[2]

This paper looks into the role of international trade in driving U.S. productivity growth. We first discuss and estimate the relationship between international trade and manufacturing productivity. We then use the estimation

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1. Some economists—for example, Gordon (1999, 2000a)—maintain that the rise in productivity growth is mainly due to cyclical forces, and is likely to fizzle away as the 1990s boom gives way to slow growth. However, others—for example, Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and Whelan (2000)—argue that both the production and the use of information technology (IT) have contributed substantially to the productivity resurgence of the late 1990s.

2. Gordon argues that "the closing of American labor markets to immigration, and of goods markets to trade, between the 1920s and 1960s gave a boost to real wages which, in turn, made labor expensive and promoted productivity growth. The post-1972 slowdown in productivity growth coincided with a reopening of labor markets to immigration and of goods markets to foreign trade."

results to impute the impact of international trade on nonfarm business productivity to gauge whether the impact is of macroeconomic significance. The reason for focusing on manufacturing productivity in the empirical analysis is threefold. First is the well documented fact that almost all of the gain in measured productivity growth in the nonfarm business sector has taken place in the manufacturing sector.[3] The second is that the U.S. manufacturing sector has seen a much greater rise international exposure than the nonfarm business sector. The third is that the proxy variables for international exposure in nonfarm business are subject to more serious measurement errors than those in manufacturing.

This paper identifies four theoretical channels through which increases in international trade affect domestic productivity: (1) economies-of-scale effects, (2) competition effects, (3) reallocation effects, and (4) spillover effects. While an increase in imports has an adverse effect on import competitors' productivity growth through the economies-of-scale channel, increases in trade volumes are expected to have positive effects on productivity growth of domestic industries through the other three channels.

We then estimate the effect of trade on labor productivity (LP) and TFP in the manufacturing sector. At the industry level, we conduct panel-data regressions to estimate the relationship between productivity and various measures of international competition or exposure—such as import prices, import penetrations, and export shares—across manufacturing industries at the 3-digit SIC level. At the aggregate level, we use time-series regressions to estimate the impacts of international exposure and competition on aggregate productivity growth in the manufacturing sector.

Three major findings are identified from the panel regression results. First, falling import prices indeed help to boost both LP and TFP growth after one to two years. Moreover, this impact is more pronounced when import penetration—i.e., the import share of domestic market—is bigger. Second, an increase in import penetration has a positive impact on LP growth with a two-year lag, even though it is negatively correlated with LP growth contemporaneously. This suggests that the positive effects of international trade outweigh the negative economies-of-scale after sufficient time lapses, even though the negative effect prevails in the short run. Third, even though export shares are positively correlated with LP contemporaneously, that correlation fades after one year. This

3. For example, Gullickson and Harper (1999) note that manufacturing TFP more or less accounts for all of the measured TFP changes in private business since 1979. Gordon (1999) also notes that all of the true structural productivity growth acceleration in nonfarm private business is explained by structural acceleration in durable manufacturing, leaving nothing for the 87% of the economy outside of durable manufacturing.

suggests that, while higher-productivity firms are more likely to export because they are more confident of recovering the initial sunk costs incurred to enter foreign markets, exporting activity by itself does not promote productivity.

The results of time-series regressions of LP growth are similar to those of panel regressions in terms of import prices and export shares, though not in terms of import penetration. Simulations based on time-series regressions show that the combination of changes in the import prices and in import penetration has contributed as much as 32 percent of average LP growth in manufacturing, and about 10 percent of LP growth in nonfarm business, over the 1996-2001 period. These results, while subject to simplifying assumptions, suggest that import competition does play an important role in driving U.S. productivity growth.

The rest of the paper is organized as follows. Section 2 discusses the theoretical channels through which international trade affects domestic productivity. Section 3 gives an overview of the data and concept used in the empirical analysis of this paper. Section 4 presents the estimation and results of pane regressions. Section 5 presents the estimation and results of time-series regressions. Section 6 conducts simulation to gauge the aggregate impact of international trade on productivity growth in the economy. Section 7 concludes.

2. Theoretical Channels: How Does Trade Affect Productivity?

We identify four channels through which international trade can affect productivity growth of domestic industries: (1) economies-of-scale effects, (2) competition effects, (3) reallocation effects, and (4) spillover effects. The first two channels directly affect productivity growth at the firm level, while the latter two affect productivity growth at the aggregate level. The first three channels affect labor productivity both directly and through their impacts on TFP, while the last channel affects labor productivity mainly through its impact on TFP.[4]

<u>Economies-of-Scale Effects</u>

International trade could affect a firm's productivity through economies-of-scale effects in two ways. The first is by moving output to a lower-cost point in the average cost curve: assuming variable costs do not rise too quickly as output increases, an increase in a firm's output decreases its average unit costs by reducing the share of average fixed costs in the unit costs of output. Through this

4. Labor productivity measures output per hour of labor, or overall production efficiency. Total factor productivity measures output per combined unit of labor and capital input, or technical progress. Section 3 gives a more elaborate account of these two measures of productivity.

along-the-cost-curve effect, an exporting firm's labor productivity rises when exports lead to an increase in its output, while an import-competing firm's labor productivity falls when imports crowd out its market share and lead to a drop in its output.

The second type of economies-of-scale effect results in shifting the average cost curve downward: the expectation of higher output through exporting offers incentive for exporting firms to undertake fixed-cost investment, including R&D, thereby enhancing their potential productivity. This "dynamic" economies-of-scale effect thus helps boost TFP through the added incentive for exporters to pursue "true technical progress." Arguably, the dynamic effect is likely to matter more for exporting firms than for import-competitors, as technology is more likely to progress along with (exporters') R&D investment than it is to regress along with (import-competitors') R&D divestment.

Competition Effects

International competition in the form of lower-priced foreign goods may play a key role in the productivity growth of import-competing firms. As competition intensifies—whether foreign or domestic—manufacturing firms will be forced to improve productivity if they want to stay competitive without cutting profit margins. However, as Baily and Gersbach (1995) documented for the US auto industry, domestic competition alone may not provide sufficient incentives to adopt best-practice technologies; only increases in the geographic range of competition will ensure most efficient production.[5] Under competitive pressures, domestic firms can raise TFP in a number of ways—by investing in R&D, by corporate restructuring, by learning from foreign competitors through the reverse-engineering of their products, or by imitating foreign competitors' production processes.[6]

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5. Baily and Gersbach (1995) argued that "productivity is improved by competition and that it is improved most when the competition is global." They argue that "Increasing the geographic range of competition increases the opportunities for absorbing a new and more productive production process, especially if the range of competition includes best-practice companies. As long as US auto companies, for example, did not compete against Japanese companies, they were unwilling to risk making radical changes in their production methods. Barriers to the adoption of best practice production methods can thus explain why regional competition is not enough to ensure best-practiced productivity."

6. If cheaper foreign imports are *inputs* into the production process rather than competing final goods, this could lower firms' costs, improve their profit margins, and perhaps dissuade them from adopting best-practices. However, the import share of total inputs is still small. Campa and Goldberg (1997) find that about 4% of inputs in US manufacturing industries were imported in 1975, and about 8% were imported in 1995.

Reallocation Effects

Increases in international trade could boost aggregate productivity growth through three types of reallocation effects:

(1) As the more efficient of import-competing firms survive while the less efficient are forced to exit, the average productivity growth at the industry level will rise.

(2) Higher-productivity plants are more likely to enter foreign markets because they are more confident that their initial entry costs will be recovered. After entry, the increase in their markets allows higher-productivity exporting firms to expand faster than in a closed economy. Increases in international trade thus could help augment industry-wide productivity growth by allowing higher-productivity exporting firms to represent a larger share of their industries.

(3) Inexpensive imports will displace domestic production in lower-productivity industries. Domestic resources in these industries are released and reallocated to industries further up the ladder of technological sophistication, raising average productivity growth in the manufacturing *sector* as a whole.

Spillover effects

Romer (1986) pointed out the possibility that an individual firm's R&D efforts could spill over to affect the stock of knowledge available to all firms. A firms face constant returns to scale to all private inputs, but its level of technology depends on the aggregate stock of all firm's knowledge, so that the production function of firm ***i*** is characterized as $Y_i = A(R)\, F(K_i, L_i, R_i)$, where Y_i , K_i, L_i, R_i are respectively output, capital input, labor input, and the stock of knowledge of firm *i*, while *R* is the aggregate stock of knowledge in the economy. From this perspective, an increase in international exposure could raise overall productivity growth through two types of spillover effects:

(1) The increase in R&D by domestic firms in response to international exposure—for example, through import-competing firms' responses to international competition and exporting firms' incentive to exploit the economies-of-scale effect through exports—will increase the aggregate stock of knowledge, thereby raising aggregate productivity.[7]

7. See, for example, Rivera-Batiz and Romer (1991), Ben-David and Loewy (1998), and Feeney (1999).

(2) Domestic firms—both import-competitors and exporters—could upgrade their technology by learning from and adopting the best-practice technologies of foreign competitors. The aggregate stock of knowledge available to domestic firms thus could increase as their exposure to foreign firms and foreign stocks of knowledge increases, thereby boosting aggregate productivity.[8]

Through these four channels, an increase in international trade is likely to have a net positive impact on domestic productivity growth. To be sure, some import-competitors' productivity growth will be adversely affected by international exposure through the economies-of-scale channel. However, it is questionable that the negative economies-of-scale effect will dominate the positive effects for all import-competing firms. Moreover, even as some firms' productivity growth are being eroded by international exposure, aggregate productivity growth will still benefit from international trade through the reallocation channel as productivity-losing firms become a smaller share, while productivity-gaining firms become a bigger share, of their industries.

3. Overview of Data and Related Issues

Before empirically testing whether the theoretical trade channels have a net positive impact on manufacturing productivity growth, we give an overview of data on productivity and international trade and issues related to these data.

3.1 Productivity Growth

The relationship between LP growth and TFP growth can be derived from the growth accounting first suggested by Solow (1957). Under the assumption of constant returns to scale and competitive markets, the rate of output growth is the weighted sum of output growth accrue to labor, capital, or technical progress:

$$(1) \qquad g_y = a\, g_n + (1-a)\, g_k + q$$

where g_y, g_n and g_k are the growth rates of output, labor hours and capital, respectively, a is the share of labor in output, and q is the Solow residual or TFP. TFP thus constitutes the part of output growth unexplained by growth in production input and is attributed to technical progress. Subtracting g_n from both sides of (1), one can see that labor productivity growth $(g_y - g_n)$ is a combination of capital deepening $(g_k - g_n)$ and TFP growth:

8. See Coe and Helpman (1995).

$$(1') \quad g_y - g_n = (1-a)(g_k - g_n) + q.$$

It should be noted that reported TFP is subject to a number of measurement errors, and thus may not reflect the change in productivity due to "true technical progress." Chief among the measurement errors is the heterogeneity in the quality or "service flow" of capital and labor inputs.[9] In addition, measured productivity growth not attributable to "true technological progress"—such as that derived from cyclical fluctuations, economies of scale, and reallocation effects—may also be lumped into measured TFP.

Reported productivity growth in the U.S. nonfarm business sector accelerated strongly after 1995 from its prolonged stagnation. However, the acceleration appears merely to have returned the average rate of productivity growth to the rate that prevailed during 1960-1974 (Table 1). This pattern pertains to both LP and TFP. LP growth in nonfarm business, after averaging nearly 3 percent per year during 1960-1973, dropped to a meager 1.4 percent annual rate during 1974-1995; it has since revived but not resumed its pre-1974 rate. Likewise, the average rate of TFP growth has recovered since 1995, after a sharp slowdown over 1974-1995, but it is still considerably below its 2 percent rate over the 1960-1973 period.

Productivity growth in manufacturing—growth in both LP and TFP—is considerably more upbeat than that in nonfarm business. To begin with, productivity growth in manufacturing did not suffer as much of a slowdown as did nonfarm business. Moreover, the growth acceleration in manufacturing after 1995 has brought the average post-1995 growth rates of both LP and TFP beyond their average rates during 1974-1995. LP growth rates averaged 3 percent during 1960-1973, dipped to 2.7 percent during 1974-1995, then surged to 4.4 percent during 1996-2000. Likewise, TFP growth rates averaged 1.7 percent during 1960-1973, dropped to 0.7 percent during 1974-1995, and then soared to 2.1 percent during 1996-2000.

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9. For example, a one-dollar increase in the stock of computer equipment provides more productive services per period than a one-dollar increase in the stock of office buildings. Likewise, one- hour labor of a high-skilled worker provides more productive services than one-hour labor of a low-skilled worker. Clearly, failure to account for quality improvements in either labor or capital would overstate historical TFP growth.

   The Bureau of Labor Statistics (BLS) takes into account changes in labor and capital quality in its measurements of TFP. BLS' computation of labor input growth includes both the increase in raw hours worked and the change in the skill composition (as measured by education and work experience) of the work force. Likewise, BLS constructs real capital stocks as vintage aggregates of historical investments according to a service flow concept. See BLS Handbook of Methods (1997), Chapter 10.

The above overview indicates that LP growth and TFP growth have roughly moved in tandem. This comovement could be due to the fact that both growth rates are procyclical.[10] But it also indicates that LP growth has been driven more by changes in the rate of technical progress than by capital deepening. The overview also confirms what most analysts have agreed: even after allowing for the fact that measured productivity growth in service sectors may be biased downward, most of the productivity acceleration in nonfarm business in the past decade is driven by that in the manufacturing sector. As shown in Figure 1, LP growth in manufacturing has increasingly surpassed that in nonfarm business since the early 1970s, and that wedge has become even more pronounced since 1994. The wedge between TFP growth in manufacturing and that in nonfarm business, which did not emerge until the early 1980s, has also widened since the early 1990s (Figure 2). It appears that manufacturing industries have enhanced productivity through labor-saving investment and technical progress much more than non-manufacturing industries since the early 1990s.

3.2 Openness to International Trade

A casual observation of the U.S. trade numbers tends to suggest that the U.S. economy is still 'effectively insulated' from foreign competition.[11] Despite the sustained rise in imports and exports since the early 1970s, the imports/GDP ratio was only about 14 percent, and the exports/GDP ratio about 10 percent in 2002. Such trade ratios are not much larger than their values in the early 1980s and suggest that U.S. economic growth and fluctuations are mainly driven by domestic demand.

The picture is quite different, however, if one looks at the rise in the international exposure of the manufacturing sector. The import share of manufactured shipments has tripled from 8 percent in 1981 to 24 percent in 2001. The export share of manufactured shipment rose from 9 percent to 16 percent over the same period. Indeed, as indicated in Figures 3 and 4, the increase in manufacturing's exposure to international competition since 1970 is much higher than that in either the nonfarm business sector or in the economy as a whole. It is interesting to note that the manufacturing sector—which was less exposed to

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10. The literature offers three main theories on why productivity is procyclical. First, business cycles may be driven mainly by exogenous changes in production technology. Second, productivity may be procyclical because of economies of scale: the economy endogenously becomes more efficient by moving to higher levels of activity. Third, reported factor (labor and capital) input tends to overstate the true amount of input in down times, giving rise to the procyclicality in *measured* (as opposed to *true*) productivity. See Basu (1996).

11. For example, see Krugman (1994, 1995)

international competition than nonfarm business before 1985—became much more exposed to international competition than the nonfarm business sector after 1985,[12] the year that productivity growth—both LP and TFP—in manufacturing began to outstrip productivity growth in nonfarm business unambiguously. That phenomenon supports the hypothesis that international exposure exerts a net positive impact on productivity growth.

The rise in the manufacturing sector's exposure to international competition is even more vividly portrayed by the increase in the number of industries facing greater import penetration since 1970. As Table 2 shows, the share of manufacturing industries (at 4-digit SIC level) exposed to import penetration greater than 20 percent was only 6 percent in 1970. That share jumped to 13 percent in 1980, then surged to 32 percent in 1990, and reached 40 percent in 1996. In 1970, manufacturing industries exposed to import penetration greater than 50 percent represented only 1 percent of the about 400 manufacturing industries in the sample. By 1996, that share already reached 12 percent.

While it is true that the share of manufacturing output in the economy has been shrinking, manufacturing industries continue to play an important role in the aggregate economy. It is well established that productivity growth in the manufacturing sector has been mainly responsible for the productivity resurgence after 1995. Clearly, an accurate indicator of the degree with which the U.S. economy interacts with the rest of the world needs to take into account of the U.S. manufacturing sector's exposure to international trade.

4. Panel Data Analysis

We use panel data from 40 manufacturing industries at the 3-digit SIC level to estimate several variants of equation (2):

$$(2)\ \Delta\Gamma_{j,t} = \alpha_j + \sum_{i=1}^{n} \beta_i \Delta RP_{j,t-i} + \sum_{i=1}^{n} (\gamma_i MP_{j,t-i})\Delta RP_{j,t-i} + \sum_{i=1}^{n} \varphi_i \Delta MP_{j,t-i} + \sum_{i=1}^{n} \delta_i \Delta X_{j,t-i} + \theta \Delta CU_t + \mu_{j,t}$$

where,

α_j is the constant representing the trend growth in industry ***j*;**

12. The import share of nonfarm business output rose from 12 percent to 16 percent, while the export share rose from 10 percent to a mere 12 percent, from 1981 to 2001. The import share in the nonfarm business sector is constructed as *goods and services imports/ nonfarm output*. The export share is constructed as *nonagricultural goods and services exports/nonfarm output*.

$\Delta\Gamma_{j,t}$	is the percent change in labor productivity, or TFP, in industry ***j*** at time ***t;***
$\Delta RP_{j,t}$	is the percent change in the relative import price—import price relative to PPI—in industry ***j*** at time ***t***;
$\Delta MP_{j,t}$	is the first difference in the import penetration ratio (= import/(shipment-imports+exports)) for industry ***j*** at time ***t***;
$\Delta X_{j,t}$	is the first difference in the export share (exports/shipment) in industry ***j*** at time ***t;***
$\Delta CU_{j,t}$	is the first difference in capacity utilization, in industry ***j*** at time ***t.***

The constant term α_j is included to control for average trend productivity growth in industry *j*. ΔCU_{jt} is included to account for the procyclicality of productivity growth in industry *j;* consequently, θ is expected to be positive. By including α_j and ΔCU_{jt} in the panel regression, we aim to estimate the effects of international exposure on productivity growth beyond and above what can be accounted for by the trend growth and cyclical fluctuations.

A negative β and γ would suggest that *decreases* in import prices, by intensifying competitive pressure, help to promote US manufacturing productivity. In this way, a negative and significant β and γ would lend support to the competition effects described in Section 2. By the same token, we would expect a positive φ, since the competition effects, reallocation effects, and spillover effects all suggest that a rise in import penetration would help promote productivity growth. On the other hand, a negative φ would indicate the less probable scenario that the negative economies-of-scale effect dominates the other positive channels. Finally, a positive δ would indicate that, all else equal, productivity growth tends to increase when exports become a larger share of total shipments. This would be consistent with the economies-of-scale channel, the reallocation channel, and the spillover channel.

To find out the dynamics of the trade-productivity relationship, we estimate equation (2) in three ways: (1) i = 0, n = 0; (2) i = 1, n = 1; (3) i = 1, n = 2.

4.1 Panel Data

Annual data at the 3-digit SIC industry level, from 1989 through 1996, are used for the regression analysis. Due to the limitation imposed by industry productivity data, the sample used for LP regressions consists of just 40 manufacturing industries, while that used for TFP regressions consists of 35 industries. This gives 320 (= 40 x 8 years) cross-sectional time series observations for each variable in the LP regressions, and 280 (=35 x 8 years) observations for each variable in the TFP regressions. Table 3 gives a detailed report of the characteristics of these industries.

Industry data on labor productivity, total factor productivity, import prices, and domestic prices are obtained from the Bureau of Labor Statistics (BLS). Industry data on import value, export value, and shipment are from the U.S. Census Bureau. Capacity utilization by industry is from the Board of Governors of the Federal Reserve System.[13]

4.2 Panel Results

For both LP and TFP regressions, the basic specification in equation (2) is estimated with fixed-effects and random-effects regressions.[14] The results on LP growth regressions are reported in Tables 4 & 4a. To avoid the problem arising from the multicollinearity between $MP*\Delta RP$ and ΔRP, Table 4 reports results of regressions that exclude $MP*\Delta RP$ as an explanatory variable, while Table 4a reports results of regression that exclude ΔRP as an explanatory variable. In the same fashion, the results on TFP regressions are reported in Tables 5 & 5a.[15]

In all four tables, the coefficient estimate on ΔCU is statistically significant and positive. This finding confirms the well-known procyclicality of both LP and TFP growth. More important, they confirm that the coefficient estimates on international variables adequately controlled for cyclical impacts on productivity growth.

Labor Productivity Growth

Overall, the results of fixed-effects and random-effects regressions are compatible qualitatively and quantitatively, with both indicating that imports and import-price competition has a net positive impact on LP growth in manufacturing industries. Four main observations emerge from Tables 4 and 4a:

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13. Capacity utilization data are from http://www.federalreserve.gov/releases/G17/ipdisk/utl.sa. (For data before 1986, see http://www.federalreserve.gov/releases/G17/iphist/utlhist.sa.) For industries where capacity utilization data are not available at 3-digit SIC level, we use the closest 2-digit SIC level as a proxy.

14. Both fixed-effects and random-effects regressions allow intercepts to vary, while keeping other coefficients fixed, across industries. The fixed-effects method does so by using industry dummies for the constant. The random-effects method makes specific assumptions about the distribution of the intercepts. Consequently, if the restrictive distributional assumption of the random-effects method is correct, using that additional information leads to a more efficient estimator.

15. When both $MP*\Delta RP$ and ΔRP are included in the regressions, the coefficient estimates on ΔRP become statistically insignificant, but the point estimates on $MP*\Delta RP$ become bigger than those reported in Tables 4, 4a, 5, and 5a.

(1) A sustained decrease in the relative import price (*RP*) has a positive and significant impact—both quantitatively and statistically—on LP growth after one to two years. This is seen in Table 4 where the coefficient estimate on ΔRP_{t-1} is negative and statistically significant in the random-effects regression (-0.118) , and the sum of coefficient estimates on ΔRP_{t-1} and ΔRP_{t-2} is negative and significant in both types of regressions (-0.253 in fixed-effects and -0.303 in random-effects). The results suggest that a sustained one percent drop in the average *RP* results in about 0.3 percentage-points increase in LP growth over two years.

(2) In the short run, the negative economies-of-scale effects of an increase in import penetration (*MP*) unambiguously outweigh its productivity-enhancing effects— competition effects, reallocation effects, spillover effects— for import-competing industries. Over time, however, the productivity-enhancing effects become increasingly dominant, yielding a net positive impact on LP growth. This pattern is seen most clearly in Table 4a: ΔMP has a negative and significant correlation with LP growth contemporaneously, but this correlation turns insignificant after one year and positive and significant after two years. The pattern can also be detected in Table 4, albeit with a lower level of statistical confidences.

(3) The competition impact of a given degree of change in the relative import price (ΔRP) is bigger when and where import penetration is bigger. This result is seen in Table 4a where the coefficient estimate on the interactive term ($MP_{j,t-1}*\Delta RP_{j,t-1}$) is significant and negative in the random-effect regression (-0.006), and the sum of coefficient estimates on $MP_{j,t-1}*\Delta RP_{j,t-1}$ and $MP_{j,t-2}*\Delta RP_{j,t-2}$ is significant and negative in both types of regressions (-0.013 in fixed effects and -0.016 in random effects). These results suggest that the impact of a 1 sustained percent decrease in RP_j will increase labor productivity in industry *j* by about ($1.5*MP_j$) percent over two years.

(4) An increase in export shares (ΔX) is positively correlated with LP growth contemporaneously, but does not have a significant or positive effect on LP growth after one year. This suggests that the contemporaneous correlation is due to the fact that higher-productivity firms are more likely to export because they are more confident that the initial sunk costs incurred to enter foreign markets will be recovered and that exporting activity *per se* does not promote productivity.

Total Factor Productivity Growth

As in LP regressions, the results of fixed-effects and random-effects regressions of TFP are compatible quantitatively and qualitatively, with both indicating that imports and import-price competition will have a net positive impact on TFP growth in manufacturing industries. Four notable findings emerge from Tables 5 and 5a:

(1) A sustained decrease in the relative import price (*RP*) begins to boost TFP growth after one year, and that positive impact builds up as time goes on. In Table 5, the coefficient estimate on ΔRP_{t-1} is statistically significant and negative in both types of regression (- 0.089 in fixed effects and - 0.090 in random effects), as is the sum of coefficients on ΔRP_{t-1} and ΔRP_{t-2} (-0.27 in fixed effects and -0.22 in random effects). This suggests that a sustained one-percentage decrease in ΔRP increases TFP growth cumulatively by about 0.25 percentage points over two years.

(2) In the short run, the negative economies-of-scale effect of an increase in import penetration outweighs the productivity-enhancing effects in import-competing industries. Over time, however, the positive effects grow sufficiently to offset the negative economies-of-scale effect. This pattern is shown in both Tables 5 and 5a: in both types of regression, ΔMP is negatively correlated with TFP growth contemporaneously, but the sum of coefficient estimates on lagged ΔMP become positive and statistically insignificant.

(3) The impact of a decrease in the relative import price on TFP growth is greater when import penetration is greater, and that impact builds up over time. This pattern is exhibited in Table 5a: the coefficient estimate on $MP_{t-1}*\Delta RP_{t-1}$ is negative and significant (-0.007 in both types of regressions), and the sum of coefficient estimates on $MP_{t-1}*\Delta RP_{t-1}$ and $MP_{t-2}*\Delta RP_{t-2}$ becomes even more negative (-0.015 in fixed effects, and -0.011 in random effects) and more significant.

(4) An increase in export share *(ΔX)* is not significantly correlated with TFP either contemporaneously or with lags, suggesting that exporting activity by itself does not boost productivity growth.

The results of LP and TFP panel regressions suggest that international trade spurs manufacturing productivity growth mostly through imports rather than exports. Import competition boosts not only LP growth but also TFP growth in manufacturing industries. The coefficient estimates on the international variables in TFP regressions are smaller in magnitude, and are estimated with a lower level of confidence, than those in the LP regressions. This suggests that improvement in LP growth stems from capital deepening as well as TFP growth.

5. Time-Series Analysis

In this section, we use OLS regressions and time-series data to estimate the impact of international exposure on productivity growth in the manufacturing sector. We estimate equation (3):

$$(3)\ \Delta\Gamma_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta RP_{t-i} + \sum_{i=1}^{n} (\gamma_i MP_{t-i})\Delta RP_{t-i} + \sum_{i=1}^{n} \varphi_i \Delta MP_{t-i} + \sum_{i=1}^{n} \delta_i \Delta X_{t-i} + \theta \Delta CU_t + \mu_t$$

where,

α is the constant term representing the trend growth rate of LP or TFP in the manufacturing sector;
$\Delta\Gamma$ is the first difference of the log of either LP or TFP in manufacturing;
ΔRP is the first difference of the log of the relative import prices (price of imported goods/producer prices);
ΔMP is the first difference of import penetration in manufacturing;
ΔX is the first difference of export share (exports/shipment) in manufacturing;
ΔCU is the first difference of capacity utilization in the manufacturing sector.

The expectation and interpretation of the parameters in equation (3) are similar to those in equation (2).

5.2. Time-Series Data

For LP regressions, because quarterly data on manufactured exports and imports are not available before 1978, we use quarterly data from 1978:Q1 to 2001:Q4. For TFP regressions, because TFP data are available only annually, we use annual data from 1970 to 2000. To capture the dynamics of trade-productivity relationship, we set n = 4 or 8 quarters in LP regressions and n = 1 or 2 years in TFP regressions.

Labor productivity (indexed at 1992=100) and total factor productivity (indexed at 1996=100) are obtained from the Bureau of Labor Statistics.[16] Prices

16. The Bureau of Labor Statistics measures LP as output per hour of labor for major sectors—private business and private nonfarm business—as well as manufacturing, but it measures TFP differently for major sectors than for manufacturing. For major sectors, TFP is measured as the *value-added* per combined unit of labor and capital input. For aggregate manufacturing and manufacturing industries, TFP is measured as *output* per combined unit of capital, labor, energy, materials, and purchased business services inputs.

of goods imported and the producer price index (PPI) are obtained from the Bureau of Economic Analysis. Annual data on manufactured exports and imports, available beginning in 1970, are obtained from *The Statistical Abstract of the United States 2002*. Quarterly manufactured exports (imports) are obtained by adding up exports (imports) of manufactured goods in four SITC categories: SITC05, SITC06, SITC07, and SITC08.[17] Data on manufactured exports, imports, and shipments are all from the U.S. Census Bureau.

5.2 Time-Series Results

The estimation results of equation (3) are reported in Table 6. As in the panel regressions, to avoid the problem arising from the multicollinearity between $MP{*}\Delta RP$ and ΔRP, columns (a) and (b) report results that exclude $MP{*}\Delta RP$ as a regressor, while columns (c) and (d) report results that exclude ΔRP as a regressor.[18] Table 6 shows that both the constant and the coefficient estimate on ΔCU are positive and significant in LP as well as in TFP regressions, indicating that the estimations on international variables are generated after properly controlling for the trend growth rate and the effect of business cycles.

The results of time-series regressions are not exactly the same as those of panel regressions. This should not come as a surprise since only up to 40 manufacturing industries, whose combined shipment represents about 32 percent of total manufacturing shipment, are studied in the panel regressions.

For LP regressions, the coefficient estimates on ΔX, ΔRP, and $MP{*}\Delta RP$ are similar to those in the panel regressions, though those on ΔMP are not. The sum of coefficient estimates on lagged ΔX is insignificant, suggesting that exporting activity by itself does not boost productivity. A decrease in the relative import price has a positive impact on LP growth: the sum of coefficient estimates on ΔRP_{t-i} is -0.18 when $i = 1$ *to 4 quarters* and grows to -0.21 when $i = 1$ *to 8 quarters*. In comparison, the sum of coefficient estimates on ΔRP_{t-i} in the panel regressions, based on the random-effect results reported in Table 4, is -0.12 when $i = 1$ *year* and grows to -0.30 when $i = 1$ *to 2 years*. It is reassuring that the quantitative effect of ΔRP on LP growth estimated in the time-series regression does not differ much from that estimated in the panel regressions, even

17. For documentation of SITC classifications, see the web site of the Statistical Division of United Nations: http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=14 .

18. When both $MP{*}\Delta RP$ and ΔRP are included in the regressions, the coefficient estimates on ΔRP become statistically insignificant, but the point estimates on $MP{*}\Delta RP$ become bigger than those reported in Table 6.

though the effect appears to take place somewhat faster in aggregate than in the 40 industries studied in the panel analysis. Of course, this result could also suggest that most of the impact of international trade on LP growth occurs at the industry level.

As in the panel regressions, the time-series regressions also find that the impact of ΔRP on LP growth grow in tandem with import penetration—that is, the coefficient estimates on $MP*\Delta RP$ are negative and significant. The sum of coefficient estimates on $MP_{t-i}*\Delta RP_{t-i}$ is -0.018 when *i = 1 to 4 quarters* and grows to -0.023 when *i = 1 to 8 quarters*. In comparison, the sum of coefficient estimates on $MP_{t-i}*\Delta RP_{t-i}$ in the panel regression, based on the random-effect results in Table 4a, is -0.006 when *i = 1 year* and -0.016 when *i = 1 to 2 years*. The coefficients on $MP*\Delta RP$ are somewhat greater here than those in panel regressions, but not to a puzzling degree. Many factors could have contributed to the difference in the coefficient estimates. For example, when inexpensive imports displace domestic production in lower-productivity industries and release resources to produce higher-value products, aggregate productivity growth will increase but industry productivity growth may not. Alternatively, this result could also suggest that the impact of import-price competition on productivity is more sensitive to the size of import penetration for the industries excluded from the panel study than for those 40 industries that are included.[19]

Unlike in the panel results, an increase in import penetration has neither a negative and significant correlation with LP growth contemporaneously, nor a positive and significant impact on LP growth over time. This result could be due to the fact that the power of test in estimating the coefficient on ΔMP is greater in the panel analysis than in the time-series analysis, as the former uses a sample of 40 industries with a high variation in MP distribution while the latter's sample lacks that cross-industry variation.

For TFP regressions, the estimation results are less similar to those of panel regressions than what we found for LP regressions. While coefficient estimates on ΔX and ΔMP are qualitatively similar to those in the panel regressions, those on $MP*\Delta RP$ and ΔRP are not. In other words, we find that exports share does not boost TFP growth while an increase in import penetration does help to increase TFP growth with a two-year lag. However, changes in the relative import price do not have a statistically significant impact on TFP growth, even if we allow that impact to vary with import penetration. Again, this difference could stem from the fact that panel regressions have a greater power of test than time-series regressions.

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19. This difference in sensitivity could also be due to the fact that the average import penetration of the 40 industries included the panel regressions (31% during 1989-1996) is bigger than that in the manufacturing sector (15% during 1989-1996).

From the viewpoint of growth accounting, the time-series finding that an increase in import penetration helps to boost TFP growth—after sufficient time has lapsed—but not LP growth appears irreconcilable, since LP growth is the sum of capital deepening and TFP growth. Indeed, this results are the opposite of what we find in the panel analysis. Which set of results is more credible?

It appears that both economic intuition and the statistical power of test demand that we give more credit to panel results than time-series results. As we already argued, the power of test in the time-series estimations is not as great as in the panel estimations. Moreover, the economic implication of the time-series results—that the negative economies-of-scale effect of an increase in *MP* completely offset all its positive effects (i.e., competition effect, reallocation effect, and spillover effect)—are less plausible than the opposite which is implied by the panel results. The choice is obviously in favor of the panel results, and that in turn suggests that we should give more credibility to LP results, rather than TFP results, of time-series regressions. Finally, the fact that LP regressions—which use quarterly data—enjoy a higher degree of freedom than the TFP regressions—which use annual data—also help lend credibility to LP regression results.

6. International Trade's Contribution to Aggregate Productivity Growth

This subsection estimates the contribution of import competition to labor productivity growth in the manufacturing sector and in the nonfarm business sector over the 1981-2001 period. We first use results of time-series regressions to conduct simulations to find out the contribution of international trade to manufacturing LP growth over the 1981-2001 period. We then use these simulated results to impute the contribution of import competition to LP growth in nonfarm business.

6.1 Contribution to Productivity Growth in Manufacturing

To assess the contribution of international trade to LP growth in the manufacturing sector over 1981-2001, we first use the coefficient estimates reported in Table 6 to simulate what the growth rates of labor productivity in manufacturing would have been if import prices had not changed since 1978. That is, we first use the coefficient estimates to project the in-sample forecast of growth rates of manufacturing labor productivity. We then use the coefficient estimates to project what the growth rates of manufacturing labor productivity would have been if $\Delta RP = 0$. (Given that the coefficient estimates on ΔX and ΔMP are statistically insignificant, the simulation allows both ΔX and ΔMP to be what they were historically.) The contribution of ΔRP to manufacturing LP growth rates is then obtained by subtracting hypothetical LP growth rates from the in-sample forecast, or fitted value, of growth rates.

Table 7 reports the contribution of *ΔRP* and *MP*ΔRP* to manufacturing LP growth in three sub-periods (1981-1987, 1988-1995, and 1996-2001) that roughly follow the pattern of the dollar exchange rate's swings (see Figure 5).[20] The upper panel in Table 7 shows that, although rising and falling in tandem with *ΔRP*, the contribution of import competition to manufacturing LP growth has been quantitatively significant. The influence of the dollar exchange rate on manufacturing productivity growth is also quite palpable. If we take the simulation results seriously, *MP*ΔRP* contributed 0.41 percentage-points to the 3.39 percentage-point increase in the average growth rate of manufacturing labor productivity during 1981-1987, roughly a 12 percent contribution. The contribution then fell to 7 percent (=0.19/2.68) during 1988-1995, then rose to 32 percent(=1.20/3.76) during 1996-2001. Note that, because import penetration has been rising steadily and the depreciation of the dollar during 1986-1995 was not sufficiently passed through to increase the average relative import price, the net contribution of *MP*ΔRP* to manufacturing LP growth during 1988-1995 was still positive, though lower than in 1981-1987 or 1996-2001.

6.2 Contribution to Productivity Growth in Nonfarm Business

To impute the impact of international trade on labor productivity in the nonfarm private business (NFPB) sector, it is useful to think of the impact on NFPB productivity growth as the sum of the impacts on two main subsectors of NFPB:

$$(4) \quad \Delta\Gamma_t^{NFPB} = \omega_{1t}\,\Delta\Gamma_t^{M} + \omega_{2t}\,\Delta\Gamma_t^{NM}$$

where $\Delta\Gamma_t^{NFPB}$, $\Delta\Gamma_t^{M}$, and $\Delta\Gamma_t^{NM}$ is respectively the impact of international trade on labor productivity growth in nonfarm business, in manufacturing, and in nonmanufacturing at time t; ω_{1t} is the share of manufacturing output, and ω_{2t} is the share of nonmanufacturing output, in the nonfarm business sector at time t.

We already have obtained an estimate of $\Delta\Gamma_t^{M}$ in the previous section. The question now is: what is a reasonable estimate of $\Delta\Gamma_t^{NM}$? It is quite conceivable that international trade would have direct effects on output in

20. Figure 5 shows that our sample period can be roughly divided into three sub-periods by the behavior of the dollar exchange rate—the 1978-1985 period of dollar appreciation, the 1986-1995 period of dollar depreciation, and the 1996-2001 period of dollar appreciation. However, because *ΔRP* and *MP*ΔRP* are estimated to take one-to-two years to affect productivity and because we are keen in assessing international trade's contribution to the post-1995 productivity growth revival, Table 7 reports their contributions in three sub-periods that do not exactly synchronize with the dollar's swings.

nonmanufacturing industries such as transportation, banking and other financial service industries, thereby enhancing productivity growth through the economies-of-scale effect, if nothing else. However, it is hard to see how those effects would show up in the official productivity data, as service-sector productivity tends to depend on payroll data inordinately, a tendency that may bias measures of LP growth toward zero and may understate growth in TFP. For these reasons, we opt for assuming that $\Delta\Gamma_t^{NM}$ is zero, and that $\Delta\Gamma_t^{NFPB} = \omega_{1t}\,\Delta\Gamma_t^{M}$.

With this simplifying assumption, our computation indicates that that *MP*ΔRP* contributed 0.10 percentage-points to the 1.71 percentage-point increase in the average growth rate of NFPB labor productivity during 1981-1987, roughly a 6 percent contribution (see the lower panel in Table 7). The contribution then fell to 3 percent (=0.04/1.35) during 1988-1995, then rose to 10 percent during 1996-2001.

7. Conclusion

This paper argues that increasing international trade could affect domestic productivity through competition effects, economies-of-scale effects, reallocation effects, and spillover effects. The paper then estimates the empirical relationship between international exposures and productivity growth in manufacturing industries (through panel regressions) and in the manufacturing sector (through time-series regressions).

The results of both panel and time-series regressions indicate that increases in import competition indeed have a positive and significant impact on manufacturing productivity growth, even though increases in exports do not. The strong and unambiguous effect of changes in import prices on productivity growth suggest that the competition channel and the reallocation channel operate quite powerfully, even if the evidence is less clear for the economies-of-scale effect and the spill-over effect. The results also indicate that the relationship between international exposure and productivity growth is dynamic rather than static, evolving over time.

Our simulation results indicate that import competition's contribution to aggregate productivity growth has become quite pronounced during 1996-2001, a period of a sustained dollar appreciation. Together, the increase in import penetration and the decrease in import prices have contributed to 32 percent of labor productivity growth in manufacturing, and to 10 percent of labor productivity growth in nonfarm business, during 1996-2001. These results suggest that import competition has unmistakably helped boost U.S. productivity growth.

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Figure 1. U.S. Labor Productivity Growth
(Annual Growth, 1960-2002)

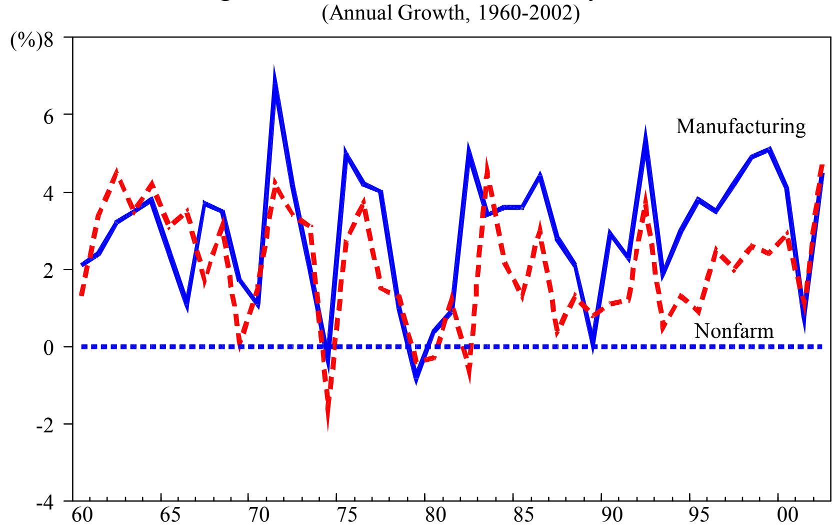


Figure 2. U.S. Total Factor Productivity Growth
(Annual Growth, 1960-2001)

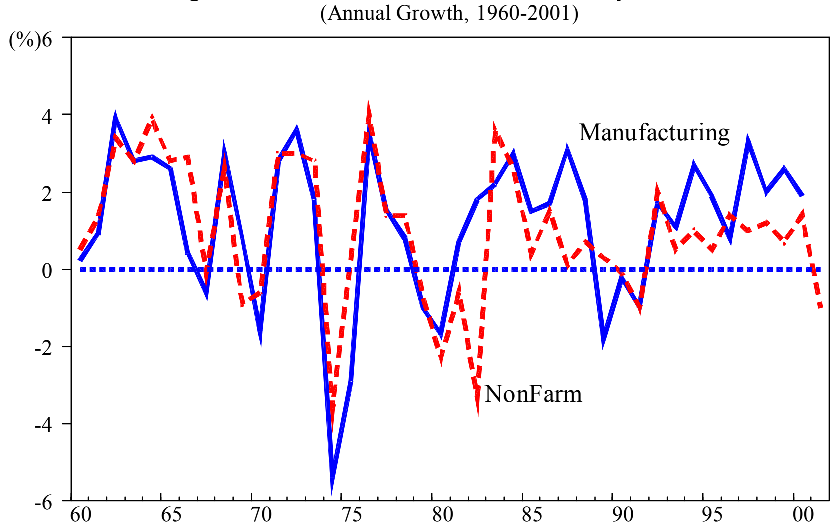


Figure 3. U.S. Imports Share by Sector
(1970-2001)

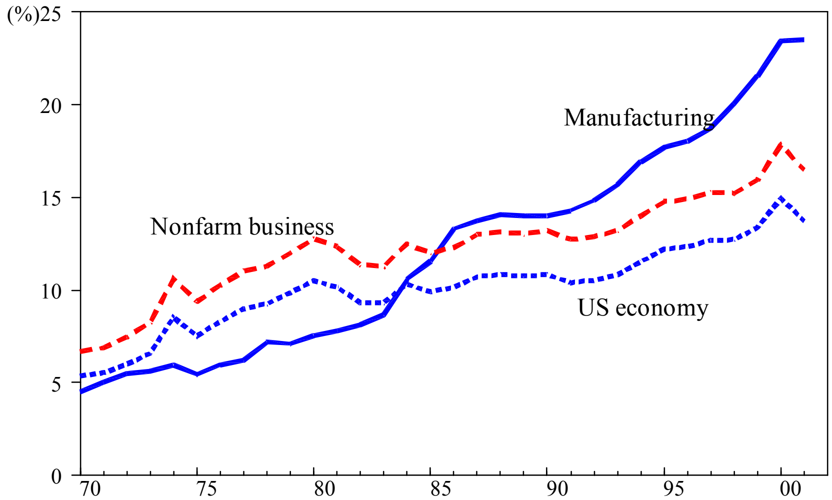


Figure 4. U.S. Exports Share by Sector
(1970-2001)

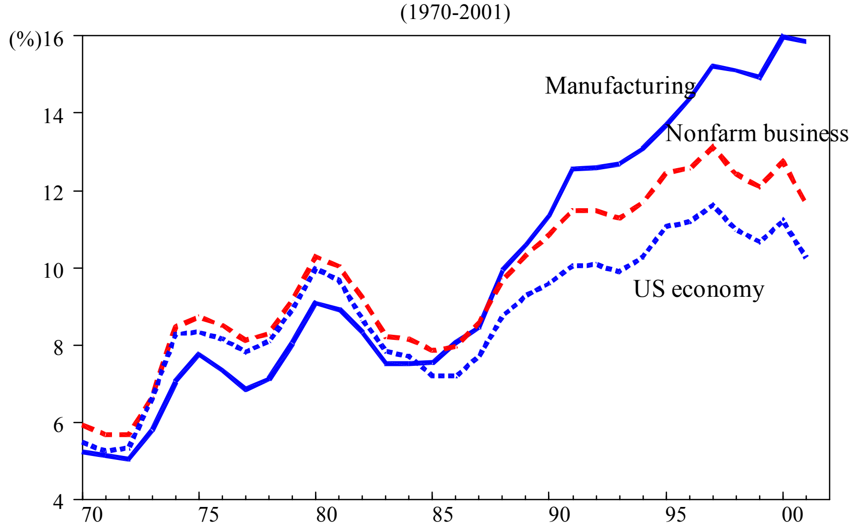
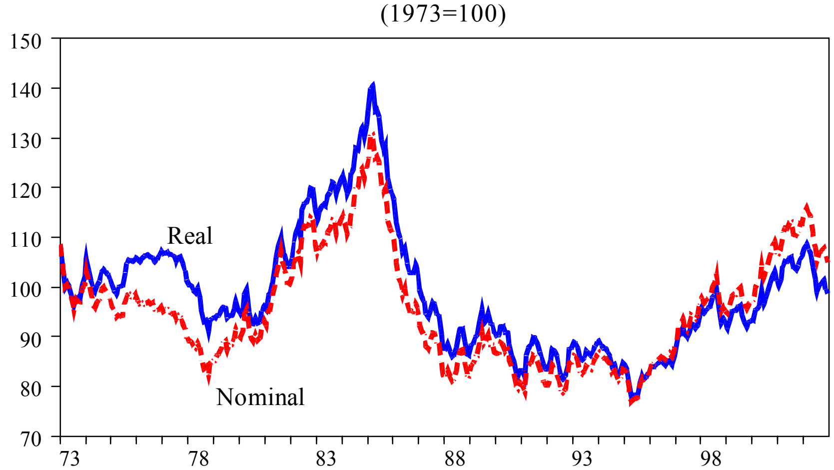


Figure 5. Trade-Weighted Dollar Exchange Rate vs. Major Currencies
(1973=100)



Source: Federal Reserve Board of Governors

Table 1. Productivity Growth in U.S. Manufacturing and Nonfarm Business
(Average annual growth rate, percent)

	1960-1973	1974-1995	1996-2000	2001	2002
Labor Productivity					
Nonfarm Business	2.9	1.4	2.5	1.1	4.7
Manufacturing	3.0	2.7	4.4	0.8	4.6
Total Factor Productivity					
Nonfarm Business	2.0	0.4	1.2	NA	NA
Manufacturing	1.7	0.7	2.1	NA	NA

Table 2. The Distribution of Manufacturing Industries by Import Penetration over Time

Import Penetration (IP) (Percent)	1958	1970	1980	1990	1994	1996
0 # MP # 10	92	84	70	46	43	42
10 < MP # 20	4	10	17	22	20	18
20 < MP # 30	2	4	6	13	14	15
30 < MP # 40	0	1	3	6	8	9
40 < MP # 50	0	1	2	5	6	6
50 < MP # 60	0	1	1	3	4	3
60 < MP # 70	0	0	0	2	2	3
70 < MP # 80	0	0	0	1	2	2
80 < MP # 90	0	0	0	1	1	2
90 < MP # 100	0	0	0	1	1	2
0 # MP # 100	100	100	100	100	100	100
Total Number of Industries	431	431	431	346	398	398

NOTES:
1. This table is adopted from Gamber and Hung (2001).
2. MPi = M*i*/(S*i*-X*i*+M*i*), where M*i* is imports, S*i* is shipments, X*i* is exports, in industry *i*.
3. The distribution is in terms of the percent share of 4-SIC industries by in each range of import penetration.

Table 3. Average Shipment Share, Import Penetration, and Export Share for a Sample of 40 Manufacturing Industries

SIC #	Industry	Shipment Share 1987-96	Import Penetration 1989-96	Export Share 1989-96
201 *	Meat Products	6.5	4.4	9.9
202	Dairy Products	4.8	1.6	1.6
203	Preserved Fruits & Vegetables	3.8	6.8	6.0
206	Sugar & Confectionery Products	0.6	34.4	28.0
207	Fats & Oils	2.0	6.5	14.5
208	Beverages	5.5	6.9	2.7
209	Miscellaneous Food & Kindred Products	2.2	9.2	6.9
221	Broad woven Fabric Mills, Cotton	0.6	20.7	10.8
222	Broad woven Fabric Mills, Manmade Fiber & Silk	0.9	15.5	10.8
229	Miscellaneous Textile Goods	0.9	12.5	14.0
232	Mens' & Boys' Furnishings	0.8	57.8	21.0
238	Miscellaneous Apparel & Accessories	0.2	62.9	19.9
242	Sawmills & Planing Mills	2.4	16.6	10.0
243	Millwork, Plywood & Structural Members	2.5	5.2	4.1
259	Miscellaneous Furniture & Fixtures	0.4	71.2	52.8
261 *	Pulp Mills	0.7	52.9	50.9
262	Paper Mills	3.4	19.8	13.4
281 *	Industrial Inorganic Chemicals	2.2	20.2	26.6
289	Miscellaneous Chemical Products	2.0	6.1	14.0
301	Tires & Inner Tubes	1.2	19.5	11.9
314	Footwear, Except Rubber	0.4	67.7	10.6
317	Handbags & Personal Leather Goods	0.1	64.9	8.9
326	Pottery & Related Products	0.3	41.5	15.4
331	Blast Furnace & Basic Steel Products	5.4	18.9	7.1
333	Primary Nonferrous Metals	1.4	52.9	49.2
335	Nonferrous Rolling & Drawing	3.8	11.4	14.3
345 *	Screw Machine Products, Bolts, etc	0.6	22.7	14.9
353	Construction & Related Machinery	2.9	21.2	38.0
355	Special Industry Machinery	2.0	29.4	31.0
362	Electrical Industrial Apparatus	1.2	34.0	31.8
363	Household Appliances	1.8	20.0	14.3
364	Electric Lighting & Wiring Equipment	1.5	28.9	23.6
366	Communications Equipment	2.0	47.2	44.2
369	Miscellaneous Electrical Equipment & Supplies	1.8	42.3	43.0
371	Motor Vehicles & Equipment	25.1	28.3	15.3
382	Measuring & Controlling Devices	2.4	29.1	43.8
386	Photographic Equipment & Supplies	1.9	28.2	21.6
391	Jewelry, Silverware & Plated Ware	0.6	74.7	53.3
394	Toys & Sporting Goods	1.1	48.6	20.9
396 *	Costume Jewelry & Notions	0.2	41.7	17.2

Source: Import and Export data are from the U.S. Census Bureau. Shipments data are from Annual Survey of Manufacturers, published by the U.S. Census Bureau.

Notes: (1) Industries with an asterisk are not included in the TFP regressions.
(2)Shipment share is an industry's shipment relative to total shipment of all 40 listed industries. The 40 industries together make up about 32% of total manufacturing shipment each other.

Table 4. Panel Regressions of Labor Productivity Growth in Manufacturing

	Fixed Effects			Random Effects		
	(a)	(b)	(c)	(a)	(b)	(c)
	No lag	1- year lag	2- year lag	No lag	1- year lag	2- year lag
ΔRP	0.064	-0.078	-0.253**	0.007	-0.118*	-0.303***
	(1.01)	(1.10)	(2.02)	(0.12)	(1.88)	(3.23)
ΔMP	-0.542***	0.105	0.528	-0.506***	0.111	0.303
	(3.56)	(0.57)	(1.59)	(3.64)	(0.69)	(1.24)
ΔX	0.297***	-0.184	-0.338*	0.281***	-0.159	-0.201
	(2.83)	(1.53)	(1.75)	(2.88)	(1.50)	(1.25)
ΔCU	0.461***	0.405***	0.359**	0.542***	0.514***	0.517***
	(3.47)	(2.73)	(2.04)	(4.60)	(4.12)	(3.55)
Adjusted R^2	0.181	0.123	0.153	0.133	0.092	0.068

Table 4a. Panel Regressions of Labor Productivity Growth in Manufacturing

	Fixed Effects			Random Effects		
	(a)	(b)	(c)	(a)	(b)	(c)
	No lag	1- year lag	2- year lag	No lag	1- year lag	2- year lag
MP*ΔRP	0.004	-0.003	-0.013**	0.001	-0.006**	-0.016***
	(1.64)	(1.15)	(2.51)	(0.35)	(2.17)	(4.12)
ΔMP	-0.583***	0.112	0.645**	-0.517***	0.140	0.494**
	(3.77)	(0.61)	(2.03)	(3.64)	(0.87)	(1.96)
ΔX	0.304***	-0.183	-0.318*	0.284***	-0.165	-0.239
	(2.90)	(1.53)	(1.65)	(2.91)	(1.55)	(1.49)
ΔCU	0.472***	0.404***	0.357**	0.543***	0.506***	0.531***
	(3.57)	(2.73)	(2.04)	(4.59)	(4.07)	(3.69)
Adjusted R^2	0.187	0.124	0.167	0.137	0.096	0.110

NOTES: (1). Contemporaneous coefficient estimates on ΔCU for all columns. In column (b), coefficient estimates are for 1-year lag. In column (c), coefficients are the sum of coefficient estimates over 2 lagged years.
(2). *** denotes 1% significance level; ** denotes 5%, and * 10%, significance level.
(3) Numbers in parentheses are absolute values of t-statistics.

VARIABLES: RP = relative import price, MP = import penetration, X = exports share, CU = capacity utilization.

Table 5. Panel Regressions of TFP Growth in Manufacturing

	Fixed Effects			Random Effects		
	(a)	(b)	(c)	(a)	(b)	(c)
	No lag	1- year lag	2- year lag	No lag	1- year lag	2- year lag
ΔRP	0.039	-0.089*	-0.273***	0.044	-0.090*	-0.221***
	(0.78)	(1.62)	(2.72)	(0.95)	(1.80)	(2.89)
ΔMP	-0.248**	0.050	0.138	-0.214*	0.065	0.026
	(1.94)	(0.33)	(0.47)	(1.77)	(0.49)	(0.12)
ΔX	0.117	-0.069	-0.135	0.073	-0.096	-0.090
	(1.38)	(0.72)	(0.80)	(0.91)	(1.15)	(0.65)
ΔCU	0.235**	0.229**	0.205	0.411***	0.495***	0.359***
	(2.25)	(1.93)	(1.39)	(4.74)	(6.08)	(3.12)
Adjusted R^2	0.231	0.179	0.104	0.308	0.230	0.163

Table 5a. Panel Regressions of TFP Growth in Manufacturing

	Fixed Effects			Random Effects		
	(a)	(b)	(c)	(a)	(b)	(c)
	No lag	1- year lag	2- year lag	No lag	1- year lag	2- year lag
MP*ΔRP	0.002	-0.007***	-0.015***	0.002	-0.007***	-0.011***
	(0.78)	(2.75)	(3.39)	(0.81)	(2.83)	(3.26)
ΔMP	-0.257**	0.078	0.193	-0.221*	0.083	0.056
	(1.98)	(0.52)	(0.66)	(1.81)	(0.62)	(0.25)
ΔX	0.117	-0.064	-0.072	0.074	-0.084	-0.069
	(1.39)	(0.67)	(0.42)	(0.92)	(1.00)	(0.50)
ΔCU	0.238**	0.220*	0.240*	0.412***	0.420***	0.378***
	(2.27)	(1.88)	(1.64)	(4.73)	(4.69)	(3.20)
Adjusted R^2	0.231	0.202	0.125	0.308	0.271	0.137

NOTES: (1). Contemporaneous coefficient estimates on ΔCU for all columns. In column (b), coefficient estimates are for 1-year lag. In column (c), coefficients are the sum of coefficient estimates over 2 lagged years.
(2). *** denotes 1% significance level; ** denotes 5%, and * 10%, significance level.
(3) Numbers in parentheses are absolute values of t-statistics.

VARIABLES: RP = relative import price, MP= import penetration, X = exports share, CU = capacity utilization.

Table 6. Time-Series Regressions of Manufacturing Productivity
(Numbers in parentheses are absolute values of t-statistics.)

	Dependent Variable: Δln(LP)				Dependent Variable: Δln(TFP)			
	(a) 1 year	(b) 2 years	(c) 1 year	(d) 2 year	(a) 1 year	(b) 2 year	(c) 1 year	(d) 2 year
CONSTANT	0.006*** (5.27)	0.005*** (2.95)	0.006*** (4.97)	0.005*** (2.95)	0.007 (1.39)	-0.005 (0.84)	0.006 (1.27)	-0.005 (0.87)
ΔRP	-0.18** (2.40)	-0.21** (1.95)	NA	NA	-0.06 (1.05)	-0.01 (007)	NA	NA
MP*ΔRP	NA	NA	-0.018** (2.63)	-0.023** (2.54)	NA	NA	-0.011 (1.55)	-0.005 (0.55)
ΔMP	0.64 (1.28)	0.67 (0.80)	0.67 (1.35)	0.52 (0.62)	0.74 (1.14)	2.36** (2.72)	0.68 (1.07)	2.28** (2.55)
ΔX	0.00 (0.00)	0.82 (1.22)	-0.11 (0.24)	0.59 (0.93)	-0.30 (0.51)	0.62 (0.94)	-0.27 (0.47)	0.67 (1.05)
ΔCU	0.21*** (3.36)	0.24*** (3.59)	0.22*** (3.62)	0.23** (3.52)	0.30*** (3.08)	0.31*** (3.32)	0.31*** (3.33)	0.31*** (3.54)
Adjusted R^2	0.12	0.19	0.14	0.19	0.46	0.57	0.49	0.58

Notes:

1. Labor productivity (LP) regressions use quarterly data from 1978:Q1 to 2001:Q4. Coefficients on ΔCU are estimates on the contemporaneous quarter. Coefficients on all other variables are the sum of coefficient estimates over 4 lagged quarters for columns (a) and (c), and that over 8 lagged quarters for columns (b) and (d).

2. TFP regressions use annual data from 1970 to 2001. Coefficients on ΔCU are estimates on the contemporaneous year. Coefficients on all other variables are the estimates on one-year lag for columns (a) and (c), and the sum of estimates on one-year and two-year lags for columns (b) and (d).

3. VARIABLES: RP = relative import price, MP = import penetration, X = export share, CU = capacity utilization.

4. *** denotes 1% , ** 5%, and * 10%, significance level.

Table 7. Net Impact of Import Competition on US Labor Productivity Growth
(Simulation results based on Table 6)

	Yearly Average, Percent		
	1981-1987	**1988-1995**	**1996-2001**
Manufacturing LP growth	**3.39**	**2.68**	**3.76**
LP growth contributed by *ΔRP* (based on column b)	0.50	0.13	0.65
LP growth contributed by *MP*ΔRP* (based on column d)	0.41	0.19	1.20
Nonfarm Business LP growth	**1.71**	**1.35**	**2.25**
LP growth contributed by *ΔRP* (based on column b)	0.12	0.03	0.12
LP growth contributed by *MP*ΔRP* (based on column d)	0.10	0.04	0.23
Memo:			
ΔRP (change in the relative import price)	-2.2	-1.5	-2.8
MP (Import Penetration)	9.8	14.1	18.6
MP*ΔRP	-15.1	20.4	-50.7
Manufacturing GDP/Nonfarm Business GDP ratio	23.7	21.6	19.0