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6

Does a Kick in the Pants Get You Going or Does It Just Hurt? The Impact of International Competition on Technological Change in U.S. Manufacturing

Robert Z. Lawrence

International competition and technological change are frequently treated as independent sources of change. Anne Krueger (1980) pointed out, for example, that productivity growth was a far more important source of employment shifts in U.S. manufacturing than import competition. Similarly, the debate over growing wage inequality in the United States over the past 2 decades has been split between those emphasizing trade and those emphasizing technological change. There are, however, reasons to question the implicit assumption that trade and technology are independent causes. Indeed, it is likely that causation runs in both directions. Changes in technology are surely an explanation for trade flows and international competition could well affect technological change. Ignoring these interactions could be seriously misleading.[1] In particular, if international competition induces technological change, it could be a more important source of employment and wage changes than studies assuming their independence might conclude.

Moreover, the effect of international competition on technological

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1. Kapstein (1996), for example, dismisses the studies that have found a strong role for technology and a weak role for trade on the grounds that trade has induced technological change. Similarly, Wood (1994, 167) has argued that "in the North many firms have reacted to Southern competition by devising new production techniques that use less unskilled labor."

change is an important subject in its own right. It is often argued that the dynamic effects of free trade, for example, are far more important than the static benefits that come from improved resource allocation. Indeed, it is these dynamic effects that are believed to explain the evidence that more-open economies grow faster (Sachs and Warner 1995).

In this paper, therefore, after a brief conceptual review, I explore the effect of international competition on technological change empirically. Empirical work is particularly important since this effect is theoretically ambiguous. Competition could indeed spur innovation but it could also stifle it by making it less profitable. "Sometimes," as the saying goes, "a kick in the pants gets you going," but "sometimes it just hurts." However, resolving this issue in the data is no easy matter because "trade" and "technological change" are endogenous as well as interdependent variables.[2] One major challenge for this work, therefore, is dealing with issues of simultaneity. Indeed, throughout this paper I will show how results obtained using ordinary least squares (OLS) specifications may be dramatically changed when endogeneity is controlled for. A second major challenge lies in selecting appropriate measures of technology and international competition. In the paper I will proxy "international competition" with both price and quantity measures, and "technology" with measures of total factor productivity (TFP) and the skill ratio (i.e., the ratio of employment of workers with some college education to those with a high school degree or less).

In this paper I will present results in which both price and quantity measures suggest that import competition had a positive impact on U.S. TFP growth in manufacturing in the 1980s. This impact was larger in industries that are relatively less skill intensive and on average stronger in industries competing with developing countries. In the face of an elastic demand for the products of these industries, therefore, this effect would have actually raised the relative wages of less-skilled workers. I will also present evidence that import competition may have stimulated the rising skill intensity in manufacturing. This effect could have contributed to the rising skill premium.

6.1 Theory

It is not a simple matter to predict and measure the impact of increased international competition on the rate and direction of technological change at the industry level. One difficulty relates to the ambiguity of the effects in theory, another to the practical problems in distinguishing technical change from other shifts in resource allocation. There are several theoretical considerations that suggest that the impact of increased inter-

2. See Deardorff and Hakura (1994).

national competition on innovation (1) could be either negative or positive and (2) could well differ in export and import-competing industries.

One impact of international competition could come from "learning by doing." Productivity growth could be related to the scale of operation. To the degree that these effects are external to the firm but related to the size of the industry, we might expect to see positive effects in export industries that expand in response to increased trade and negative effects in import-competing sectors that would contract in response to trade.

A second impact could stem from "learning by watching." Trade will expose firms to new competitors and ideas. To the degree they are able to learn from foreign competitors, this could stimulate innovation in all exposed sectors. In this case, the effects should be positive for both export and import-competing sectors.

A third impact could occur through endogenous responses to the changes in market structure as a result of increased international competition. Here, as with competition in general, the arguments are varied. On the one hand, there is the view, often ascribed to Hicks, that "monopolists seek the quiet life" and will tend to rest on their laurels and avoid innovations, particularly when these might undermine the rents they enjoy from existing technologies. In this view, the increased rivalry over market share gives competitive firms a greater incentive to develop new products and processes that will help them defend their market position. On the other hand, there is the view of Schumpeter that too much competition can retard innovation, particularly if the rewards from innovation are rapidly eroded. Indeed, the rationale for patents rests precisely on the view that temporary monopolies are required to induce innovation. In addition, even monopolists may have incentives to innovate strategically to continue to exclude rivals and to reduce production costs. In fact, it is likely that neither perfect competition nor pure monopoly are conducive to innovation, and that intermediate market structures that provide a combination of rents to innovation and competitive pressures will do more to stimulate innovation, which suggests that the impact of increased international competition depends on whether the industry initially has more or less than the optimal balance of rents and competition.

A fourth impact could occur because of economies of scale. Once knowledge is obtained, marginal costs may be close to zero, but obtaining knowledge may entail large fixed costs. The implication, as Adam Smith recognized long ago, is that the extent of the market can play a crucial role in achieving cost reduction. Firms innovating for global markets, therefore, may be able to realize these scale economies far better than those confined to local markets. Indeed, Rivera-Batiz and Romer (1991) have demonstrated how increased economic integration can cause a permanent increase in the worldwide rate of growth.

Fifth, as in any economy, in an open economy changes in relative prices will affect resource allocation and the returns from particular productive activities. In a price-taking small open economy, improvements in the terms of trade will create an incentive to shift resources toward export industries and away from import-competing industries. Similar effects might occur as a result of the reduction of trade barriers. Under these circumstances, in the short run, export industries would become more profitable, while import-competing sectors would become less profitable. The volume of trade rises, but the incentives to invest, in both innovation and in physical capital in exports and import-competing industries, would be very different. If new investment embodied new technologies, we would not find it surprising that until resources had been reallocated, productivity growth was particularly rapid in export industries and sluggish in those competing with imports. Research and development (R&D) spending and other innovation activity could, similarly, follow the same patterns.

There are paradigms that are different from those of traditional profit maximization in which managers may be stimulated to innovate when international competition threatens their rents. This involves the existence of managers who satisfice rather than maximize and behave under conditions of what is sometimes termed bounded rationality. Basically, they do not innovate continuously, but do so when subjected to an unusual stimulus. In this world, increased import competition may spur competition, while the greater profitability of exports could actually do the reverse.[3]

Thus far I have considered innovation in general. But assuming that international competition does stimulate innovation, there is also an issue of the direction in which innovation is likely to occur—in particular, whether innovation will be biased toward saving particular factors of production. The rewards to improvements in production technology will relate to the benefits from cost reduction it brings about.[4] These benefits will depend on (1) the relative costs of performing the research to save on the use of particular factors, (2) the share of particular factors in costs, and (3) the scale of output—the benefits of reducing unit costs are larger, the larger the scale of operation. If there are fixed costs in discovering a way to make unskilled labor more attractive (e.g., investing in discovering the best training methods), it will be more attractive to undertake such discoveries, the greater the share of unskilled labor in the production process. This suggests that if international trade raises the incentives to innovate in a particular industry, it could also stimulate changes that save on the factor of production used relatively intensively in that industry.[5]

International trade may also increase awareness of alternative technolo-

3. See Rodrik (1992).

4. For a discussion of factor bias see Binswanger (1974).

5. Adrian Wood (1994) has suggested that competition with developing countries could induce skill-biased technological change. He argues that competitive pressures induce producers of unskilled-intensive products to automate, that is, to use factors that are relatively cheaper in developed countries (i.e., capital and skilled labor). But, as Wood realizes, this

gies in a particular direction. In the case of competition with other developed countries, the technologies may or may not have a particular factor bias. However, since developing countries are unlikely to be pioneering more skill-intensive or automated production technologies, the channel that operates through emulation is unlikely to lead to greater automation when developed countries experience competition from developing countries. We would not expect technological changes in developed countries such as the United States to use more capital- or skill-intensive production methods when experiencing competition from developing countries.

This discussion has focused on the direct impact of international competition on industry-specific innovation. It should be noted, however, that there may also be general equilibrium effects. To the degree that increased import competition with labor-intensive products operates through Stolper-Samuelson effects to raise the relative cost of skilled and educated workers, we might expect technological change to save on other factors and to use unskilled labor more intensively throughout the economy. What we have seen in the United States, for example, is that the use ratio of skilled workers has increased and the wage of skilled workers has increased. This implies necessarily that the share of skilled workers in the wage bill has increased. If an invention can save a certain quantity of more-skilled labor, therefore, it will become more attractive. So we might expect that the bias that will result from the relative price effects will tend to result in relatively more-skilled-labor-saving technical change.

In sum, therefore, expanded trade could subject domestic U.S. industries to price pressures. These pressures, in turn, could stimulate innovation and inspire emulation. But they could, by lowering profitability and the scale of operations, reduce innovation. In addition, trade could alter the costs and incentives for both neutral and factor-biased technological change.

However, undertaking empirical work is not easy. It is important to make clear what we mean by technological change. In this study, the term implies a change in the production function, that is, the set of available technologies of production, and not resource shifts among known technologies. In practice, however, it is difficult to distinguish outward shifts in the production function from the effects of changes in the composition of output. Trade may be expected to induce increased specialization—a phenomenon that could occur within as well as between industries. For example, if international competition induced a U.S. automobile firm to outsource its labor-intensive parts production to Mexico, measured productivity might rise, but this might reflect a change in activities, rather than a technological improvement.

requires the additional assumption that the actors were previously operating under bounded rationality because it raises the question of why they were not moved to adopt these techniques earlier.

Similarly, increased competition could lead to the elimination of the least efficient firms and the expansion of the more productive firms—again, not necessarily innovation—but this could shift recorded productivity for some period of time.

Third, in models of imperfect competition, firms with pricing power will have markups that depend on the demand elasticity that they face. The impact of increased competition will be to reduce these markups, raise output, and increase levels of capacity use. This again would induce a one-time shift that raises productivity, but need not reflect a technological improvement.

Finally, it should be noted that even if we could obtain precise estimates of the impact of trade on technological change, inferring the impact of these changes on wages is by no means straightforward. In some models, in which product demand is perfectly elastic, the sectoral incidence of the change is all that matters; in other cases, it is factor bias.[6]

6.2 Previous Studies

There is anecdotal and case-study evidence on the impact of import competition on innovation in the United States (see MacDonald 1994; McKinsey 1992; Dertouzos, Lester, and Solow 1989). In particular, there are accounts of the changes brought about by competition in U.S. industries such as automobiles, steel, and copier machines.[7] There have also been studies of the impact of trade on R&D spending—presumably a leading indicator of future productivity growth. Using detailed case studies and more general regression analysis, for example, Scherer (1992) and Scherer and Huh (1992) have studied U.S. firms' R&D-spending responses to international competition. They find a mixture of responses. Some firms aggressively innovated in the face of competition; others simply submitted. On average, however, in the short run, R&D-to-sales ratios declined. Companies were more aggressive the greater their domestic sales, the more concentrated the markets in which they competed, and the more diversified their domestic operations. Companies with only U.S. operations were more submissive than those with multinational holdings. Zietz and Fayissa (1992) have tested the impact of import competition on R&D expenditure in the United States and found an association that is positive, but only for high-tech industries.[8]

6. See Krugman (2000) and Leamer (1998, 2000).

7. There is also evidence that competition has affected price-cost margins. Domowitz, Hubbard, and Petersen (1986) found that imports affected prices, but according to MacDonald (1994, 721) these effects tend to be small, even in concentrated industries.

8. Benjamin and Ferrantino (1998) examine a sample of countries in the Organization for Economic Cooperation and Development and find a positive association between productivity growth and export performance, but no association between import growth and productivity.

These considerations suggest that responses to trade could be different, depending on the degree of competition in the market.[9] These studies suggest that sometimes the spur of competition seems to help, particularly when there are reasons to suspect the domestic industry might have become complacent or when it has some surplus that it could allocate to increased R&D. Indeed, MacDonald (1994) found that in the United States, increases in import competition led to large statistically significant increases in labor-productivity growth in highly concentrated industries, but not in other industries.[10]

In sum, therefore, the literature suggests that trade might have stimulated R&D and technological change, particularly in concentrated import-competing sectors. However, there remain many unsettled issues. First, these studies did not use measures of TFP as the measure of technology. As previously noted, if trade leads to the elimination of particularly labor-intensive activities, average industry labor productivity might rise, but this would not indicate technological change. The same would be true if trade induced increased investment.[11] Second, the studies model trade as operating through the impact on quantities. To be sure, this is one way to capture trade pressures, but price channels might also be important. Indeed, import competition could depress profit margins, thereby inducing less technological change even where actual trade volumes are small. Third, there seems to have been little work on the effects of trade on the bias of technological change. This study, therefore, will try to make progress in dealing with these deficiencies. The following section will consider the impact of trade on TFP in U.S. manufacturing during the 1980s using both price and quantity measures of import competition. The next section will explore skill-biased technological change.

6.3 Trade and Total Factor Productivity Growth

6.3.1 Regression Model

Consider a regression model in which technological change, measured by TFP growth in U.S. manufacturing industries, is driven by domestic R&D intensity (*R&D*), industry concentration (*CONC*), international

9. U.S. imports from developing countries typically occur in sectors that are highly competitive, such as apparel and leather. It is thus less likely that the technology-inducing effects of the developing countries' imports will be significant. In contrast, these effects may be more important for trade with developed countries, more of which occurs in concentrated sectors.

10. Macdonald uses a model in which labor productivity growth in measured over 4-year time spans. These are regressed on the average growth in output, concentration, the change in import penetration growth in earlier period, an interaction of import penetration growth and concentration, and time dummies and other industry characteristics.

11. Indeed, Collins and Bosworth (1996) find that increased investment rather than higher TFP explains most of the association between growth and openness.

competition (T), and the interaction between concentration and competition ($CONC*T$):

$$TFP = a_1 + a_2 R\&D + a_3 CONC + a_4 T + a_5 CONC*T.$$

The incorporation of R&D as a determinant of productivity growth is straightforward. As the previous discussion makes clear, a less competitive market structure could be associated with innovation or it might detract from technological development. This structure is best captured by a measure of concentration. Capturing the impact of trade is more difficult. Traditionally, quantitative measures of imports, exports, and the trade balance have been used in productivity regressions. In this research, however, these will be supplemented by trade price measures.

Using either import prices or quantities as an independent variable, however, is problematic because these variables are not exogenous. This means that a credible estimate should control for the impact of joint causation. This will be done using a two-stage estimation procedure with instrumental variables techniques. In particular, for instrumenting import prices, a foreign cost index has been constructed by using industry-specific source-weighted foreign wholesale price indexes expressed in U.S. dollars.[12] Similarly, the endogeneity of import quantities will be controlled for with instrumental variables using a number of measures designed to capture the factor intensity of production, such as the skill ratio (skill intensity) and the ratio of plant and equipment (capital intensity), which are suggested by the Heckscher-Ohlin trade theory as likely determinants of trade. Finally, overall productivity growth (and changes in the relative use of skilled labor) could differ depending on whether competition originated from developed or developing countries. Thus, the specification will differentiate imports by their origins.

6.3.2 Data

The data are primarily from the NBER Manufacturing Database, which contains data drawn from the annual survey of manufacturing for U.S. industries at the three-digit Standard Industrial Classification (SIC) level. These data include estimates of TFP export volumes, and import volumes. Trade price data are taken from the Bureau of Labor Statistics (BLS), estimates on employment by education from the Current Population Surveys (CPS) tapes, concentration ratios and R&D spending from Scherer (1992), imports by country from Sachs and Shatz (1994), and national wholesale prices and exchange rates from the International Financial Statistics of the International Monetary Fund.

12. Import shares in 1985 are used as weights. A similar methodology was used by Revenga (1992) to estimate the impact of trade on wages.

6.3.3 Results

Import Prices

Table 6.1 reports the regression analysis undertaken for 27 three-digit industries for which import price data are available.[13] The TFP variable is the annual average change over the period of estimation. In regression 1, there is a negative relationship between TFP growth and import prices, which is statistically significant at the 90 percent level. The coefficient is sizable—each 1 percent fall in import prices induces a 0.21 percent rise in TFP. This regression suggests that competitive pressures induce technological change. However, since it is run in OLS, the regression could also reflect contamination by a common global technological shock, which induces a spurious correlation, or a shock located in the United States, which induces foreigners to lower their prices. In particular, since the United States is a large market, faster productivity growth and thus lower U.S. prices could induce lower import prices.

Indeed, regression 2 casts some doubt on the confidence we can place in the result that trade induces faster productivity growth. Once simultaneity is accounted for using the weighted foreign wholesale prices as an instrument, the coefficient is no longer statistically significant (although it does become larger). In contrast to regression 1, this result suggests no independent impact operating through the impact on prices. However, it should be noted that unfortunately the wholesale price instrument is a weak one, so that this is not a result in which we can have much confidence. In addition, we find that interacting the import price variable with the concentration variables has the effect of eliminating the significance of the import price variable (regression 3). An F-test on the import price variable and the interaction with concentration together is not significant.

The computer industry has been dummied out of the sample, since its productivity growth is so large that it could overwhelm the results. If the computer industry is added to the sample, the coefficient on import prices in the OLS version of the regression increases to 0.51 and is again significant. In addition, the coefficient on R&D also becomes significant. However, in this case as well, the coefficient loses its significance, and it declines

13. Correlations of the data for the period 1978–89 confirm two key features. First, imports from developing countries are intensive in less-skilled workers and industries that are not concentrated. Imports from poor countries relative to demand in 1978 and changes in this measure over the 1980s are positively associated with the share of high school–educated workers in employment (correlation coefficients r of 0.26 and 0.38, respectively). In contrast, imports from developed countries in 1978 had almost no relationship to the share of high school–educated employment and changes in these imports were negatively associated with this share ($r = -0.16$). Imports from developed countries in 1978 were positively associated with concentration ($r = 0.14$), whereas the coefficient for imports from developing countries was far lower ($r = 0.03$). The correlations suggest no systematic relationships between TFP growth and skill intensity. The correlation between TFP growth and the shares of high school–educated and of production workers in industry employment is very low.

Table 6.1 **TFP Change**

	Dependent Variable: TFP80-89			
	OLS (1)	TSLS (2)	OLS (3)	TSLS (4)
Constant	0.011*	0.018	0.008	−0.111
	(1.857)	(0.834)	(0.999)	(−0.068)
Concentration	0.009	0.008	0.018	0.299
	(0.656)	(0.506)	(0.883)	(0.078)
R&D	−0.244	−0.162	−0.255	−0.866
	(−1.595)	(−0.546)	(−1.636)	(−0.103)
Price change	−0.213*	−0.517	−0.023	6.914
	(−1.803)	(−0.567)	(−0.066)	(0.073)
CR*Price change			−0.517	0.299
			(−0.603)	(0.078)
$D_{computer}$	0.153**	0.142**	0.153**	0.187
	(10.971)	(3.941)	(10.816)	(0.400)
R^2	0.931	0.910	0.932	
Adjusted R^2	0.918	0.894	0.916	
F-statistic	74.11	56.48	57.64	2.75
Instrumental variable		WPPI		WPPI
N	27	27	27	27
Weighted by	*emp78*	*emp78*	*emp78*	*emp78*

Note: Numbers in parentheses are t-statistics.
Variable definitions are as follows:
TFP80-89 = average annual growth of log total factor productivity from 1980 and 1989.
Concentration = concentration ratio of the top four firms in 1977.
R&D = ratio of R&D expenditures to sales in 1977.
Price change = the average annual growth rate of log import price between 1980 and 1989.
CR*Price change = interaction term of concentration with price changes.
$D_{computer}$ = dummy variable indicating the computer industry.
WPPI = import-share-weighted change in log PPI in U.S. dollars.
The endogenous variable in TSLS is price change.
*Significant at the 90 percent confidence level.
**Significant at the 95 percent confidence level.

in magnitude in the instrumental variables estimation. Overall, therefore, these results hint at an impact of international competition on productivity growth, but it is not a relationship that is robust to specification or the use of a weak instrumental variable.

Import Quantities

In table 6.2, annual average TFP growth for 107 three-digit manufacturing industries during the period 1978–89 is explained as a function of concentration ratios, R&D-to-sales ratio, the share of exports in domestic production in the first year of the period, and import shares in domestic demand in the first year of the sample period. In table 6.3, the import-

Table 6.2 OLS and TSLS Regressions with First-Year Import Penetration, 1978–89

	Dependent Variable: TFP78-89			
	OLS (1)	TSLS (2)	OLS (3)	TSLS (4)
Constant	0.004*	0.005	0.004	0.009**
	(1.702)	(1.147)	(1.502)	(2.018)
Concentration	−0.007	0.006	−0.006	−0.004
	(−1.096)	(0.586)	(−0.930)	(−0.439)
R&D	0.082	0.219**	0.080	0.132
	(1.451)	(2.215)	(1.418)	(1.453)
Import78	0.044**	0.028		
	(3.837)	(0.487)		
LDC-import78			0.072**	−0.137
			(2.865)	(−1.389)
DC-import78			0.030*	0.044
			(1.838)	(0.687)
Export/shipments	−0.025**	−0.090**	−0.023**	−0.046**
	(−3.151)	(−2.495)	(−2.834)	(−2.059)
R^2	0.208		0.219	
Adjusted R^2	0.177		0.179	
F-statistic	6.68	1.97	5.54	1.40
Instrumental variables		*dlhsed, ky78, py78, ey78*		*dlhsed, shs79, ky78, py78, ey78*
N	107	107	105	105
Weighted by	*emp78*	*emp78*	*emp78*	*emp78*

Note: Numbers in parentheses are t-statistics.
Variable definitions are as follows:
TFP78-89 = annual average change in the log of total factor productivity over the period 1978–89.
Concentration = four-firm concentration ratio in 1977.
R&D = ratio of R&D to sales in 1977.
Import78 = ratio of imports to domestic demand (shipments − exports + imports) in 1978.
LDC-import78 = ratio of imports from developing countries to domestic demand in 1978.
DC-import78 = ratio of imports from developed countries to domestic demand in 1978.
Export/shipments = ratio of exports to domestic shipments in 1978.
Endogenous variables are Import78, LDC-import78, and Export/shipments.
*Significant at the 90 percent confidence level.
**Significant at the 95 percent confidence level.

demand variables are interacted with the concentration variables. All regressions are weighted by 1978 levels of employment. Regression 1 in table 6.2, which is run as OLS, yields a positive and statistically significant coefficient on the share of imports in domestic demand. This result is important and particularly powerful because in general we might expect that, ceteris paribus, the United States would tend to have low levels of imports in industries in which productivity growth was high; that is, the coefficient might well be biased downward. In the previous section, the use of price

Table 6.3 **OLS and TSLS Regressions with Import Penetration and Its Interaction with Concentration Ratio, 1978–89**

	Dependent Variable: TFP78-89			
	OLS (1)	TSLS (2)	OLS (3)	TSLS (4)
Constant	0.004	0.017	0.004	0.012
	(1.156)	(0.534)	(1.377)	(0.642)
Concentration	−0.006	−0.030	−0.007	−0.012
	(−0.677)	(−0.319)	(−0.832)	(−0.224)
R&D	0.082	0.222*	0.063	0.076
	(1.452)	(1.798)	(1.123)	(0.411)
Import78	0.051*	−0.128		
	(1.697)	(−0.312)		
LDC-import78			−0.031	−0.392
			(−0.531)	(−0.581)
DC-import78			0.071*	0.098
			(1.820)	(0.295)
CR*Import78	−0.016	0.465		
	(−0.246)	(0.386)		
CR*LDC-import78			0.300*	0.996
			(1.940)	(0.379)
CR*DC-import78			−0.110	−0.250
			(−1.309)	(−0.230)
Export/shipments	−0.026**	−0.097**	−0.024**	−0.040
	(−3.131)	(−2.004)	(−2.860)	(−1.426)
R^2	0.208		0.254	
Adjusted R^2	0.169		0.200	
F-statistic	5.31	1.04	4.72	1.20
Instrumental variables		*dlhsed, ky78, py78, ey78*		*dlhsed, shs79, ky78, py78, ey78, pvship*
N	107	107	105	105
Weighted by	*emp78*	*emp78*	*emp78*	*emp78*

Note: Numbers in parentheses are *t*-statistics.

Variable definitions are as follows:

TFP78-89 = annual average change in the log of total factor productivity over the period 1978–89.

Concentration = four-firm concentration ratio in 1977.

R&D = ratio of R&D to sales in 1977.

Import78 = ratio of imports to domestic demand (shipments − exports + imports) in 1978.

LDC-import78 = ratio of imports from developing countries to domestic demand in 1978.

DC-import78 = ratio of imports from developed countries to domestic demand in 1978.

CR*import78 = interaction of concentration and the share of imports in domestic demand.

CR*LDC-import78 = interaction of concentration and the share of imports from developing countries in domestic demand.

CR*DC-import78 = interaction of concentration and the share of imports from developed countries in domestic demand.

Export/shipments = ratio of exports to domestic shipments in 1978.

Endogenous variables are Import78, LDC-import78, DC-import78, CR*import78, CR*LDC-import78, CR*DC-import78, Export/shipments. Instruments are defined in the appendix.

*Significant at the 90 percent confidence level.

**Significant at the 95 percent confidence level.

changes as the measure of competitive pressures was biased toward finding a relationship and gave us reason for suspicion. However, taken together these results appear to confirm a positive effect of import competition on TFP growth. The negative coefficient on the export variable, which is significant, is surprising. The equation also indicates that the R&D-to-sales ratio is a predictor of productivity growth, although it is not significant, and concentration has a negative impact, but again is not significant. When imports are separated by origin in this OLS specification, it appears that the positive impact is associated both with imports from developing and developed countries, although the impact from developing countries is larger for any given increase in imports as a share of total demand and more statistically significant.

When the regression is estimated using two-stage least squares (TSLS), however, as in the case of the price specification, again the import variable loses its significance, although R&D is now significant. Likewise, in the TSLS specification the variables that separate imports by origin both lose their significance. However, the instruments have low *F*-statistics—an important problem which, as discussed in the appendix, gives rise to problems in interpretation. Since the import variables used in the regression reflect imports in the first year, the problem of endogeneity is likely to be less serious than in the import price specification and it is possible that given the weakness of the instruments, the TSLS estimation may do more harm than good. This suggests that it is appropriate to place more reliance on the OLS results.

In table 6.3, the interaction between the concentration ratio and imports is explored. Whereas MacDonald (1994) and others have found important interactive effects between concentration and import competition, these do not emerge strongly here. In regression 1, the significance of the import variable and the coefficient on the interaction between imports and concentration is not significant. The regression has also been estimated in a TSLS version using factor-intensity instrumental variables for the import variable. In this version of the regression, the coefficient on concentration is increased, but it is still not significant. When imports are distinguished by their origins, the influence of imports from developing countries appears to have been more important than that of imports from developed countries. However, in both the OLS and the TSLS versions of the regression, the coefficients on imports from both developed and developing countries and their interaction with concentration are not statistically significant.

It should also be reported that variables that measured changes in the share of imports over the estimation period never came in significant when entered alone or when entered in interaction with the concentration ratio. This was the case in both the OLS and TSLS specifications. Similarly, changes in imports from developed and developing countries over the estimation period were not significant in either the OLS or TSLS estimates when entered separately.

In sum, these results provide some indication that international competition with imports has raised productivity growth. It is interesting to estimate the induced impact on productivity growth that is attributable to imports and to ask whether these induced effects tended to increase or reduce the relative wages of unskilled workers. To undertake these estimates, I have used the OLS regressions in table 6.2, which produced significant effects for the impact of trade.

In the first set of calculations I derive estimates for each industry of the impact on TFP growth due to imports from all sources by multiplying the 1978 share of imports in total demand by a coefficient of 0.044. Weighted by employment, on average, TFP growth in these manufacturing industries was increased at an annual rate of 0.355 percent. When weighted by employment of the high school–educated, the impact was 0.36 percent, that is, slightly higher than the effect when weighted by employment of the college-educated, 0.34 percent. A regression of the estimated impact of imports against the share of high school–educated employment weighted by 1978 employment confirms that there was a positive relationship between the induced impact of imports and the use of unskilled labor, but it is not statistically significant.

In a second set of calculations I use the separate estimated effects of imports from developed and developing countries. For developed countries, the mean impact weighted by employment was 0.203 percent annually, larger than the weighted mean impact for imports from developed countries of 0.157 percent annually. For developing countries, the impact of trade when weighted by employment of workers with a high school education or less, 0.217 percent, was larger than the impact when weighted by employment of workers with a college education, 0.168 percent. In contrast, the impact of trade with developed countries was larger when weighted by college-educated workers, 0.163 percent, than when weighted by high school–educated workers, 0.155 percent. Added together, we obtain estimates of 0.373 percent and 0.331 percent when high school– and college-educated employment weights, respectively, are used. An employment-weighted regression of the estimated effects due to developing country imports against the share of high school–educated workers in employment yields a positive and statistically significant coefficient (t-statistic = 3), whereas a similar regression for the effects due to developed country imports has a negative coefficient that is not significant. All told, therefore, it appears as if imports had a small but positive impact on relative productivity growth in unskilled-labor-intensive sectors. The estimated impact of exports on productivity growth is negative. It also turns out that there is a statistically significant negative relationship between the share of exports in production and the share of high school–

educated employment. Thus, taking account of exports strengthens further the result that trade induced relatively faster productivity growth in low-skill industries.

In sum, therefore, these results lend support to the conjecture made by Wood (1994) that competition with developing countries has induced relatively rapid productivity growth in low-skill industries. However, if we assume that the relevant model for relating this effect to the skill premium is the traditional trade model in which world prices are given, we would have expected this effect to have lowered the skill premium (similar to an increase in the price of low-skill industries). If we abandon that model and assume an inelastic demand for U.S. products produced in low-skill sectors, we would be able to raise the estimated role played by trade in explaining the rise of the skill premium. Alternatively, if we follow Wood and assume that by the end of the period all the low-skill goods have actually become noncompeting, then this evidence would also support his view that without trade, the relative demand for unskilled workers would have been higher.

6.4 Trade and Factor Bias

There does not appear to have been a strong sectoral bias to total productivity growth. In particular, the correlations between industry TFP growth and measures of skill mix, such as the ratio of nonproduction to production workers or the ratio of high school–educated to college-educated workers, is weak. Yet it is the shift in this mix within sectors, which has been identified with skill-biased technological change, which is probably the most important source of the shift in the demand for labor. Indeed, CPS data have been used to estimated the ratio of full-time high school–educated workers (i.e., workers with a high school diploma or less) to college-educated workers (i.e., workers with some college education). These indicate that over this decade in the typical three-digit-level manufacturing industry the shift averaged about 1.15 percent annually. Weighted by employment, the shift was 1.1 percent or 12.7 percent over the decade. What accounts for this shift?

One suggested explanation relates to changes in technology—particularly to the impact of computers. A second relates more broadly to the notion that labor-management relations in manufacturing have changed as a result of production methods that demand more-skilled workers. A third possibility is that the shift has somehow been induced by international competition, that technology has shifted in manufacturing to economize on the use of production workers. In addition, however, there is a fourth possibility—that the data reflect mix effects because the international outsourcing of production worker employment has led to a concentration of production in more skill-intensive activities. A fifth notion is that firms have simply become "fat and mean." As David Gordon (1996) argued, in response to increased competitive pressures, U.S. firms have reacted by laying off their blue-collar workers, but at the same time have actually added more white-collar labor.

It is also important in thinking about this issue to distinguish between technological change and technological progress. This is particularly the case because productivity growth in the manufacturing sector has not been particularly rapid. If the "fat and mean" hypothesis is correct, for example, there might have been change, but not necessarily progress.

6.4.1 Evidence

There is evidence that some of the change is driven by new investments and R&D. Berman, Bound, and Griliches (1994) found that 40 percent of the shift toward nonproduction labor can be attributed to the introduction of computers during the 1980s. (Similarly, they found that entered alone in a regression, R&D spending accounts for just under 40 percent of the shift, and that taken together the R&D and computer variables account for about one-half of the shift away from production labor.) Krueger (1993) has found evidence linking wages and computer investment. Allen (1996) reports that returns to schooling and the wage gap between high school and college graduates increased much more in industries with a rising employment share of scientists and engineers than in other industries. He concludes that R&D activity has had an impact on relative earnings across a broad range of occupations and that the employment of college graduates increased most in industries with rising R&D.[14] Similarly Mincer (1991) found that the ratio of earnings of college graduates to earnings of high school graduates increased with R&D intensity.

There is also some empirical support for a role for trade. Feenstra and Hanson (1999) find that the rise in import penetration explains about 15 percent of the increase in the share in the wage bill of manufacturing during 1979–90 (although in some regressions they obtain higher effects). This result could be capturing changes in the ratio of production to nonproduction workers as well as their relative wages. Bernard and Jensen (1997) find that exporting explains a rise in skill intensity both because it increases growth in skill-intensive plants and because it induces a rise in skill intensity within export plants.

The literature also suggests that the distinction between technological change and technological progress could be important. In particular, while there are positive associations between the rising skill intensity and computers and capital-equipment investment, the link between these invest-

14. Allen finds that about 25 percent of the growth in the wage gap between college and high school graduates in an average industry can be explained by technological change (1996, 29).

ments and hiring decisions and productivity growth is much less apparent. Indeed, according to Berndt and Morrison (1995), increases in the share of high-tech office equipment in capital are negatively correlated with the growth in multifactor productivity, and there is only limited evidence of a positive impact on profitability. Allen (1996) reports that accelerating TFP growth is correlated with increased employment shares for high school graduates and lower employment shares for college graduates and high school dropouts.[15] These are grist for the mill of the "fat and mean" hypothesis advanced by Gordon (1996).

6.4.2 Results

The simple correlation coefficients among the variables to be used in the regression analysis are interesting. The correlation between changes in the share of high school–educated workers and the ratio of high school– to college-educated workers in 1979 is positive (0.30). Similarly, high R&D and increases in capital intensity are associated with reductions in the high school–educated share: $r = -0.4$ for R&D and $r = -0.31$ for changes in the ratio of capital to output. Variables that reflect the notion of "fat and mean" are also significant. Concentration is associated with a rise in more-educated workers ($r = 0.36$), while changes in TFP are associated with increases in the ratio of high school–educated workers rather than the reverse ($r = 0.23$). Finally, the role of imports is less significant, particularly those from developing countries. Imports may be leading to upskilling (greater skill intensity), but the effect appears to be due to trade with developed countries ($r = 0.23$) rather than developing countries ($r = 0.04$).

This correlation analysis suggests, therefore, that the increase in skill intensity has been particularly rapid in skill- and R&D-intensive sectors in which investment has been strong and in which competition, particularly in imports from developed countries, play a role. However, perhaps somewhat paradoxically, TFP has not been strong.

Table 6.4 reports the regression analysis. These use data on 107 three-digit manufacturing industries to explain changes in the ratio of high school–educated to college-educated workers (as measured by the change in the share of high school–educated workers). In this TSLS regression, variables are weighted by 1978 employment, and several variables have strong explanatory power. High initial shares of high school–educated workers are associated positively with changes in the ratio of high school– to college-educated workers (HS/COL). In other words, the declines in HS/COL tend to be large in skill-intensive industries. Increases in capital intensity are associated with statistically significant declines in the HS/COL ratio, supporting the notion of the complementarity between capital goods

15. For a more complete discussion of the impact of computers on productivity see Landauer (1995).

Table 6.4 **Changes in Employment Share of High School–Educated Workers, 1978–89**

	Dependent Variable: Change in HS/COL	
	Equation 1, TSLS	Equation 2, TSLS
High-school-share79	0.021**	0.003
	(2.073)	(0.120)
Change in output	−0.300	−0.245
	(−1.779)	(−1.482)
Change in capital/ output	−0.332**	−0.317*
	(−2.063)	(−1.803)
Concentration	−0.013	−0.003
	(−1.534)	(−0.287)
R&D	0.187	0.075
	(1.045)	(0.385)
Import78	−0.066**	
	(−3.079)	
DC-import78		−0.124
		(−1.597)
LDC-import78		0.025
		(0.284)
Change in imports	0.023	
	(0.490)	
Change in DC-imports		−0.042
		(−0.513)
Change in LDC-imports		0.074
		(0.791)
Constant	−0.014	−0.006
	(−1.489)	(−0.399)
R^2	0.193	
F-statistics	6.74	3.74
Instrumental variables	*py78, ey78, ky78, vship78, sm78*	*pemp78, vship78, sm78, py78, ey78, ky78*
N	107	105
Weighted by	*emp78*	*emp78*

Note: Numbers in parentheses are t-statistics.

Variable definitions are as follows:

Change in HS/COL = average annual change in the share of workers with high school education or less, over the period 1979–90.

High-school-share79 = share of workers with high school education or less in 1979.

Change in output = average annual change in log output.

Change in capital/output = average annual change in log(capital/output).

Concentration = concentration ratio in 1997.

R&D = ratio of R&D spending to sales in 1977.

Import78 = share of imports in domestic demand in 1978.

Change in imports = annual average change in share of imports in domestic demand over the period 1978–89.

DC-import78 = share of imports from developed countries in domestic demand in 1989.

LDC-import78 = share of imports from developing countries in domestic demand in 1989.

Change in LDC-imports = average annual change in the share of imports from developing countries in domestic demand.

Change in DC-imports = average annual change in the share of imports from developed countries in domestic demand.

Endogenous variables are Change in output, Import78, Change in imports. Instruments are defined in the appendix.

*Significant at the 90 percent confidence level.

**Significant at the 95 percent confidence level.

investment and the demand for skilled labor. Concentration is associated with declines in the HS/COL ratio (although the variable is not quite significant). Initial R&D intensity is not significant. Rapid increases in industry output are an additional significant variable—indicating it was the industries that were expanding that increased their skill ratios most. These variables, which account for most of the explanatory power, are consistent with the hypothesis that technical progress in high-skill industries associated with investment was driving the declines in HS/COL.

What role does trade play? Again, we have treated levels and changes in the ratio of imports to domestic demand as well as output growth as endogenous variables using the same instruments as in the previous regressions. The ratio of imports to domestic demand in 1978 is significant in the regression. This indicates that increases in the skill ratio were particularly rapid in industries with high levels of imports in 1978. However, changes in imports over the period are not significant. International competition appears to have played some role in shifting demand toward college graduates, and the impact does not appear to be due simply to the mix effects induced because of imports. Indeed, this result emerges even more clearly in regression 2, which differentiates imports by origin. The coefficient on the import share from developed countries is larger than that on imports in the TSLS estimation, although the t-statistic drops to 1.6. The import share of imports from developing countries is not significant. Nor is growth in imports from developing or developed countries associated with a statistically significant decline in the HS/COL ratio. Apparently, again, mix effects associated with increases in imports do not appear to be significant. Overall, therefore, there is some evidence of an association between imports from developed countries and a decline in the HS/COL ratio.

The coefficients from regression 1 can be used to estimate the overall impact of import competition from developed countries. Recall that over the period, the employment-weighted annual average decline in the share of high school–educated workers in manufacturing was 1.1 percent. Using the equation to estimate the employment-weighted average change attributable to imports suggests that it averaged 0.53 percent, about one-half of the overall change in manufacturing.

However, this shift needs in turn to be related to the economywide HS/COL ratios to derive an estimate of the impact on relative wages. In 1979, for example, manufacturing accounted for about 28 percent of high school–educated employment in the economy. Thus a decline in the share by 7.4 percent, which is the estimated impact of the induced change in the skill ratio due to trade, would represent a decline in overall high school–educated employment of 2 percent and a decline in the HS/COL ratio economywide of 4 percent. In a model with unitary elasticities of substitution, therefore, this would explain a similar 4 percent rise in the skill premium—a sizable impact.

6.5 Concluding Comments

This study has explored the impact of international competition on technological change as reflected in changes in total factor productivity and the skill ratio in U.S. manufacturing during the period 1978–89. The theoretical survey suggests that the effects of such competition could be positive or negative, with the response hinging on, among other factors, the competitive structure of the industry. Indeed, other empirical studies have found market structure important in determining the response of R&D spending and labor productivity to import competition. The empirical investigation here confirmed that international competition can affect total productivity growth. It also shows the importance of differentiating between imports from developed and developing countries.

Both the price and the quantity proxies for international competition produced statistically significant effects. In particular, trade with developing countries appears to have stimulated relatively faster TFP growth in industries with a relatively large share of imports from developing countries. Since such industries also employ relatively higher shares of workers with a high school education or less, this implies that international competition has led to relatively faster productivity growth in unskilled-labor-intensive sectors. In models with perfectly elastic product demand, this lowers the skill premium, suggesting that taking account of this impact would lower the role played by trade in explaining the skill premium.

In contrast to the case of TFP, exposure to competition with developed, rather than developing countries was associated with a more rapid increase in the ratio of high school– to college-educated employment, an impact that could have reduced the demand for unskilled workers and raised the skill premium.

In many of the regressions run for this study, most of which are not reported, there was, surprisingly, no evidence that increased imports from developed or developing countries were associated with a shift in the mix of U.S. output within industries toward relatively less-labor-intensive production methods. In both OLS and TSLS specifications, changes in the share of imports were not statistically significant.

It is appropriate to emphasize the tentative nature of these conclusions. The results obtained here are clearly very sensitive to specification and estimation technique. Theory suggests that causation runs between international competition and technological change in both directions, and the dramatic differences in results using OLS and TSLS confirm the power of this interdependence. Since, in general, we were only able to find weak instruments, this is clearly an important area for future research.

Appendix

Methodological Issues Related to Two-Stage Least Squares Estimation

In the regressions in this paper, endogeneity of the variables creates a problem that casts doubt on the validity of the OLS estimation method, which we attempt to deal with by using TSLS. In selecting appropriate instrumental variables for explaining trade quantities, variables representing the factor characteristics of production have been used. The prospective instrumental variables are searched within three categories of variables, namely, the human capital intensity, physical capital intensity, and labor intensity. We have variables of *shs79* (the share of workers with high school education or less in 1979) and *dlhsed* (the log growth rate of workers with high school education or less) to represent human capital intensities of the products. We also have *ky78* (capital intensity per output in 1978), *py78* (plants per output in 1978), and *ey78* (equipment per output in 1978) to reflect the physical capital intensities of the products. Furthermore, we regard the variables of *pvship* (the proportion of wage income in the total value of shipments in 1978) and *ppem* (the proportion of production workers in total employment in 1978) as indicating the labor intensity of the products. In table 6.1, we use *WPPI* (import-share weighted change in log PPI in U.S. dollars) as an instrument for price change (log import-price change).

One critical issue associated with using instrumental variables is whether those instruments are highly correlated with the endogenous variable, that is, the relevance of instrumental variables.[16] To test the relevance of an exogenous variable as an instrumental variable to a particular endogenous variable in the regression equation, we regress that endogenous variable on the instrumental variable and the other right-hand-side variables in the regression equation. If the coefficient of the instrumental variable is statistically significant at the 95 percent confidence level and/or the first-stage F-statistic is reasonably large (e.g., greater than 10), then this instrumental variable would be regarded as relevant or strong; otherwise it is regarded as irrelevant or weak. Unfortunately, we were generally only able to obtain weak instruments.

Given that the instrumental variables are in general not strong, in all the regressions we need to be concerned with the estimator bias caused by weak instruments in TSLS regressions. Staiger and Stock (1997) develop an asymptotic distribution theory for single-equation instrumental variables regressions when the instruments are weak. They suggest that compared with TSLS estimators, the LIML (limited-information maximum-

16. For a discussion of these issues see Bound, Jaeger, and Baker (1995), Brundy and Jorgenson (1971), Chamberlain and Imbens (1996), and Staiger and Stock (1997).

likelihood) estimator shows a smaller bias since the LIML estimator rapidly becomes median unbiased. They thus reach a constructive conclusion, for the applied work with one endogenous variable in the right-hand side of the single equation, that estimator bias is less of a problem for LIML than TSLS, so that the LIML estimator may be a better choice. We have undertaken LIML estimates particularly for those regressions that include only one right-hand-side endogenous variable and find that the estimation results are qualitatively equivalent to those of TSLS. Nonetheless, the presence of weak instruments remains a problem in this study.

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Comment Alan B. Krueger

Aristotle recognized that some questions are inherently more difficult to answer than others. If these difficult questions are really important, they are nonetheless worth trying to answer, although Aristotle argued the burden of proof that one applies would need to be relaxed in these cases. The topic of this paper is unquestionably important. In the long run, productivity growth is (almost) everything. Trade may influence productivity growth in a number of subtle and not so subtle ways, outlined by Robert Lawrence in his provocative paper. But the causal effect of trade on productivity is extremely difficult to determine. It is unclear whether much headway can be made.

To see the conceptual difficulty in ascertaining the effect of foreign competition on productivity, consider figure 6C.1, which displays isoquants in skilled (L_s) and unskilled (L_u) labor space. Initially, the industry can produce Q units of output with the combination of labor inputs indicated by the isoquant Q_1. Given relative wages, firms choose the factor/skill ratio L_u/L_{s1}, that is, point *a*. Now suppose there is an exogenous opening of trade with a country that is relatively well endowed with less-skilled workers (e.g., China). Almost everyone would expect this change in international competition to lower the wage of unskilled workers relative to skilled workers through Stolper-Samuelson effects, although there is considerable debate as to how much relative wages would change. A relative decline in unskilled wages would cause the industry to substitute unskilled for skilled workers, moving to point *b* in the diagram. Lawrence rightly does not consider this shift to be a change in productivity because the production function is constant. Instead, he would like to measure shifts in the isoquant. That is, suppose productivity increases as a result of the stimulus from trade, and the amount of skilled and unskilled labor required to produce the original Q units of output in the new regime is depicted by the isoquant Q_2. If the industry maintained its initial factor ratios, how much has productivity increased?

Figure 6C.1 highlights the considerable difficulties in answering this question. Changes in factor ratios must be accounted for. Lawrence sensibly uses total factor productivity (TFP) growth to abstract from changes in factor shares, but the TFP figures are only an approximation, and the approximation is worse as the elasticity of substitution between inputs strays from 1. Since several studies place the elasticity of substitution between college- and high school–educated workers at around 1.5, using the TFP measure will make it appear that trade matters even if all that has happened is that factor shares have shifted with a fixed production tech-

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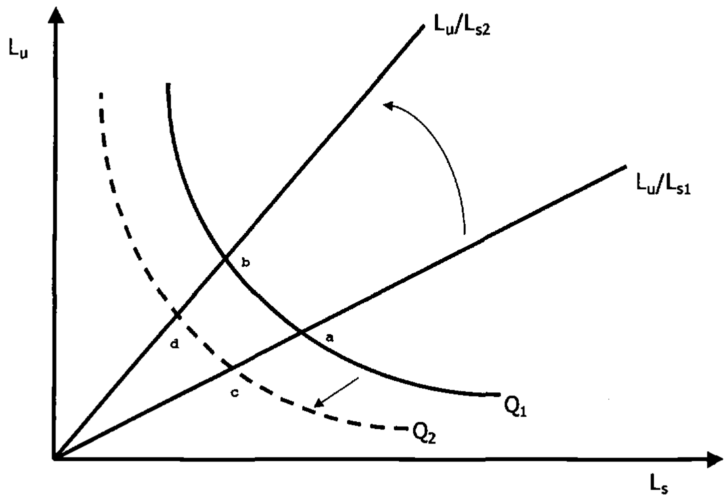

Fig. 6C.1 Hypothetical isoquants

nology.[1] Moreover, causation could run in the opposite direction. For reasons having nothing to with trade, U.S. firms could discover more efficient production techniques (shifting the isoquant from Q_1 to Q_2), driving down the price of the good and causing trade flows to shift. Causality runs from technological change to trade, not vice versa. Lawrence uses instrumental variables to address the latter problem, but as explained later, there are reasons to doubt the validity of the instruments.

A number of other conceptual and practical problems arise in the statistical analysis. Consider, for example, the problem caused by analyzing industry-level data that combine different firms and industry segments into the same three-digit manufacturing industry. It is likely that increased international competition would cause firms to close down their least productive, low-value-added plants, leaving just the high-productivity plants to be counted in the data. This selection process will make it seem as if international trade raises productivity, while in reality it might just cause low-productivity plants to go out of business—the production function is unchanged.

Also, by focusing on the intensive margin of technological change (i.e., producing existing goods better), the paper misses the effect of trade on the extensive margin (i.e., discovering new products and producing them at all). If the extensive margin is ignored, Marco Polo's importation of gunpowder to the West would be missed, for example. I suspect the extensive margin of product innovation and imitation is a major channel through

1. On the elasticity of substitution between college- and high school–educated workers, see, e.g., Katz and Murphy (1992).

which trade affects productivity. Of course, this is empirically a difficult topic to study.

Lawrence does an excellent job of cataloging the sundry ways in which trade could affect productivity. The bottom line is that theoretical reasoning provides no clear empirical prediction. I suspect the relationship between trade and technology is even more complicated than his analysis suggests. For example, there could be a "feedback loop" in which increased trade causes unskilled workers' relative wages to decline in the United States, which in turn induces companies to generate unskilled-labor-using technology, which in turn leads firms to produce more abroad because unskilled labor is really cheap abroad, and so on. Moreover, increased international competition could cause companies to devote resources to sales and marketing (e.g., more cola wars), instead of to research and development. Such advertising expenses are unlikely to have a beneficial effect on productivity.

With this background, it would be surprising if the empirical results were not open to alternative interpretations. Table 6.1 provides perhaps the most tantalizing results in the paper. These regressions relate the growth rate of TFP to changes in import prices, industrial concentration, and R&D. To address the potential simultaneity problem mentioned previously, Lawrence uses a plausible instrumental variable for import prices, foreign wholesale prices. Unfortunately, the sample consists of only 27 industries, so the results are not very precise. The OLS estimates suggest that increases in import prices lead to slower TFP growth, while the TSLS estimates yield an even larger (but statistically insignificant) negative effect of import prices on TFP growth. These coefficient estimates imply large economic magnitudes, but the imprecision of the estimates (especially the TSLS estimates) render the results almost entirely inconclusive. As I understand it, the sample size is restricted because industry price changes are only available for a small number of industries. But the reduced-form models (i.e., the relationship between TFP growth and wholesale prices) could be estimated for a much larger sample of industries. Given the magnitude of the coefficient estimates, I think these estimates would be worth calculating.[2]

Tables 6.2 and 6.3 contain the main empirical results of the paper. It seems to me, however, that the models estimated in these tables do not address the central question raised by the paper, even if the instruments were valid. In particular, the models relate TFP growth to import- and export-penetration rates. But the theoretical discussion concerns an increase in competition—a kick in the pants—not the level of competition. It is quite

2. I would also note that, unlike the TSLS estimates, the reduced-form models are not subject to small-sample bias from weak instruments.

possible that the import and export rates reflect steady-state levels, so they would provide a poor proxy for any additional stimulus to innovation due to new competitive pressures. In other words, there is no new "kick in the pants"; the boot is raised no higher than it was in steady state. I would think the appropriate explanatory variable would be the change in imports or exports. Lawrence reports, however, that when he included the change in imports as an explanatory variable it had a statistically insignificant effect.

For this reason, the results in tables 6.2 and 6.3 strike me as less than compelling. In addition, it is unclear to me why the growth rate of workers with a high school education or less is an appropriate instrumental variable for these equations because trade-induced technological change may cause a change in factor intensities. Also, as Lawrence notes, it is disconcerting that import- and export-penetration rates have opposite effects. In my opinion, it is premature to use these results to calculate the implied effect of trade-induced technological change on the relative demand for skilled and unskilled workers.

Lastly, Lawrence provides an analysis of changes in the employment share of high school–educated workers. These results complement a growing literature on the determinants of shifts in factor intensities across industries (see, e.g., Autor, Katz, and Krueger 1998). It is difficult to separate out the effect of imports on interindustry skill upgrading from the effects of skill-biased technological change due to other sources, however. This problem is not solved by the TSLS estimates; some of the variables that Lawrence uses to instrument for imports (e.g., the equipment share) could also be used as instruments for skill-biased technological change. This concern notwithstanding, there is the intriguing finding that, across industries, relatively more imports from advanced countries are associated with employment shifts away from workers with a high school degree or less, while imports from less-developed countries are essentially unrelated to skill upgrading.

I am skeptical that cross-industry analyses of trade and TFP growth can yield many definitive answers. In addition to the reservations already described, one might expect the creative process that leads to technological innovation to differ across industries. At a particular time, some industries have more scope for technological breakthroughs than others. Therefore, I think a sensible way for future research in this area to proceed would be to look across countries at the same industrial sector. For example, productivity growth in selected sectors could be compared between countries that opened up to trade and those that did not open up to trade. This type of analysis could be done for many industries. Perhaps there is much to be learned from the pattern of industries in which trade leads to productivity increases or decreases. I would think building up from such "case study" research is a more promising route to answering the important question of whether trade influences technological change.

References

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