Specialization, Fragmentation, and Factor Intensities: Evidence from Chilean plant-level data[§]

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Abstract

We examine the effects of trade liberalization on structural change by using Chilean plant-level and industry-level data. The traditional Heckscher-Ohlin (H-O) model predicts an increase in capital-labor ratios in a labor abundant country after trade liberalization. This is in marked contrast to the implications of an otherwise similar model in which trade is the result of costly fragmentation. We find a declining pattern of capital-labor ratios both at the industry and plant level. Empirical results are more consistent with fragmentation, which seems to require adjustment periods for the structural change caused by trade liberalization to take its full effect.

Key words: Fragmentation; Factor Intensity; Trade liberalization; Chile; South America

JEL Classification: F11, F14, O24

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1. Introduction

Over the past a few decades, globalization has become one of the most phenomenal events, and world trade has overwhelmingly outpaced world GDP in growth. As reported in Figure 1 using data from WTO, world trade has increased more than twenty times by 2003 since 1950 while world GDP has grown only about seven times over the same period. Along with globalization, significantly reduced international transportation costs must have contributed to fragmentation-based international trade, which is gaining more ground in today's world trade.[1] Fragmentation is defined as the splitting of a production process into two or more steps that can be undertaken in different locations but that lead to the same final product. The Economist (October 3, 1998) properly describes this pattern of trade in a survey of world trade:

> "... The days when raw materials were produced in one country and turned into finished goods in another are long gone. The making of even the simplest goods is chopped up into a number of different stages, reflecting relative costs in different countries and falling international transport costs. ... explains how a child's pinwheel, consisting of plastic sails pinned to a stick, is made in three different countries. The plastic is produced in America and cut to shape in China. The toy is then assembled in Mexico and shipped to LA for distribution. ..."

[1] See Hummels (2001) for declining transportation costs over time.

This fragmentation phenomenon has recently received more attention both theoretically and empirically. Although this phenomenon has several different names – for example, Feenstra and Hanson (1996) use the term "outsourcing" instead of the term "fragmentation" used by Jones and Kierzkowski (2001) and Deardorff (2001b) – they are only slightly different in their implications in the literature. Whatever this is called, the basic idea is that the difference in endowments across countries plays an important role in determining the pattern of international trade as in the Heckscher-Ohlin (H-O) model. The distinction between fragmentation and the traditional H-O model comes from whether a production process can be fragmented or not.

This distinction provides different implications for factor intensities – the ratios of factors employed in industries and firms – when a country adopts trade liberalization and moves toward freer international trade. Suppose this occurs in a labor-abundant developing country. According to the traditional H-O model, all industries should be led by trade to employ less labor per unit of capital because the relative price of abundant labor rises as trade causes this country to specialize in the industry that uses it intensively. This is in marked contrast to the implications of an otherwise similar model in which trade is the result of costly fragmentation. If trade is not able to achieve factor price equalization completely, then as is well known, it may be profitable for industries to use the fragmented technologies that are labor intensive. That is, in the labor abundant country, each industry will find it profitable to specialize in the more labor intensive fragment of the industry, since wages are lower in that country than in the other, even after trade has done its best to equalize factor prices. Thus instead of industries substituting capital for labor with the move to trade, as they would in the H-O model without fragmentation as trade raises the wage, we find them using more labor per unit capital, not less, because they have specialized in a labor-intensive fragment.

This bit of theory, then, motivates an empirical study of how factor intensities of plants, firms, and industries change over the course of liberalization in a developing country. Chile provides an interesting set of data to implement an empirical study of the fragmentation theory, since it reduced tariff rates from 105 percent on average in 1974 to a uniform 10 percent in 1979. We investigate the dynamics of capital-labor ratios after this dramatic trade liberalization using plant-level panel data of the Chilean manufacturing sector. Levinsohn (1999) also employed this same data set to investigate job creation and destruction effects following trade liberalization, arguing that such effects cannot be captured using industry-level data. On the other hand, Wacziarg and Wallack (2004) claim that most predictions of classical trade theory would apply to industry-level data, while acknowledging that internationally comparable plant-level data would better capture intraindustry and interfirm specialization effects.

In our study, however, the availability of plant-level data is crucial to identify the nature of structural changes following liberalization. Results from industry-level data can be simply misleading or provide ambiguous answers where dynamic structural changes are more complicated, as Levinsohn (1999) also points out. One complication comes from intraindustry production shifts. More volume of production can shift towards more labor-intensive goods following liberalization, which can reduce the capital-labor ratio of the industry while firms hire more capital per labor than before. This is another implication of the H-O model. Thus, industry-level data alone cannot identify whether the structural change is due to fragmentation or intraindustry production shifts following the H-O model.

There are some concerns about massive macroeconomic fluctuations during the sample period. In order to control for macroeconomic business cycle effects, we use a two-stage estimation procedure. In the first stage, we construct time series of the growth of plant-level capital-labor ratios by estimating coefficients of year dummy variables. These coefficients of year dummies capture the combined effects of trade liberalization and macroeconomic shocks on plant-level capital-labor ratios for each year. Macroeconomic business cycle effects are estimated in the second stage, and then we can tease out the effects of trade liberalization on the growth of plant-level capital-labor ratios from macroeconomic business cycle effects. Then the resulting values of the time series separated from macroeconomic fluctuations reveal the yearly pattern of structural changes in Chilean manufacturing plants over the sample period following trade liberalization.

The estimation results show that plant-level capital-labor ratios fall continuously after trade liberalization except for the first two years. The results for the first half of the sample period suggest that there was a turnaround in the growth of plant-level capital-labor ratios from positives to negatives or at least no positive growth immediately following trade liberalization. The results for the bottom half of the sample period strongly support fragmentation theory. The growth rates of capital-labor ratios for this period are about negative five per cent each year, and all of them are statistically very significant. The patterns of the growth of capital-labor ratios of plants that we find here are consistent with the patterns documented by Levinsohn (1999) and Pavcnik (2002).

Both studies use the same data set as this paper. Levinsohn (1999) reports negative job growth rates for the early 1980s followed by positive job growth rates in the later years. Pavcnik (2002) goes on to claim, "… plants might have responded to the changes in trade regime only after they were convinced of the government's lasting commitment to a liberalized trade regime. Hence the effects of liberalized trade might persist during the early 1980s, the period that is included in my data."

The analysis using industry-level data can be interpreted as either H-O or fragmentation. Combining this with the results of the plant-level data analysis, we find some empirical support for fragmentation theory following trade liberalization in a relatively labor-abundant country such as Chile.

The structure of this paper is as follows. Theoretical implications of trade liberalization for factor intensities are examined for the H-O model and the fragmentation theory in section 2. Section 3 describes the Chilean trade liberalization and the data used in this paper. We provide an empirical model and discuss some estimation issues in section 4. Section 5 contains estimation results, and section 6 concludes.

2. The Heckscher-Ohlin Model vs. Fragmentation Theory

How do factor intensities - the ratios of factors employed in industries and firms - change with trade liberalization? The simple textbook 2x2 Heckscher-Ohlin model has a simple answer to that question. As trade causes each country to specialize in the industry that uses its abundant factor intensively, the intensity of use of that factor must decline in order for both factors to remain fully employed, and factor prices change naturally to bring this about. The relative price of the abundant factor rises, inducing industries to economize on its use. Thus, applied for example to a labor-abundant developing country, the model predicts that all industries, both exporting and import competing, should be led by trade to employ less labor per unit of capital.

This is in marked contrast to the implications of an otherwise similar model in which trade is the result of costly fragmentation. Suppose that both industries in the H-O world permit fragmentation at some positive cost. That is, suppose that each production process can be broken into two parts, one producing an intermediate input to the other, that together yield the same final output. Each part uses capital and labor in amounts that, when added together, are somewhat larger than would be needed to produce the same output without fragmentation. The two parts use capital and labor in different proportions, and each industry has one fragment that is more labor intensive and one that is more capital intensive than the unfragmented technology of the industry.[2] We will assume further that both of the labor-intensive fragments are more labor intensive than both of the capital-intensive fragments.

Now if free trade is able to achieve factor price equalization (FPE) without resort to fragmentation, then these fragmented techniques will not be used, since they would produce the goods only at a higher cost than the non-fragmented technologies. But if the factor endowments of the two countries are sufficiently different, then, as is well known, FPE will not be possible, and a free trade equilibrium without fragmentation will retain factor prices that are somewhat unequal between the countries. In that case, it may be profitable for one or both industries to use the fragmented technologies, the labor-abundant country using the labor-intensive one in each industry, and the capital-abundant country using the capital-intensive one. Whichever of these produces the intermediate input will export it to the other, importing the final good in return. This could happen in one or both industries.

What is interesting for our purpose here is what this implies about factor intensities. If both industries specialize in the fragmented technologies at their own country's end of the factor intensity spectrum, then factor intensities will change in the opposite direction from their change in the H-O model. That is, in the labor abundant country, for example, each industry will find it profitable to specialize in the more labor intensive fragment of the industry, since wages are lower in that country than in the other, even after trade has done its best to equalize factor prices. Thus instead of industries substituting capital for labor with the move to trade, as they would in the H-O model as trade raises the wage, we will find both of them using more labor per unit capital, not less, because they have specialized in a labor-intensive fragment. Of course, for this to occur and keep factors fully employed, resources will have to shift towards whichever sector has the least labor intensive fragment. That could be either sector, but in either case, this reallocation looks a bit perverse from a H-O perspective.

The bottom line, then, is that trade with fragmentation will be different from trade without it in the observable sense that factor intensities move in opposite directions. If we observe in a labor-abundant country with trade liberalization that firms and industries increase their capital-labor ratios, then this suggests conventional H-O trade that is raising the relative wage and causing substitution out of labor. If on the other hand we observe in such a country that capital-labor ratios are falling, in firms and industries, then

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[2] This would be true necessarily if fragmentation were not costly. However, since the total factor requirement of the two fragments is greater than that of the unfragmented technology, it is conceivable that

that suggests fragmentation of production, firms discontinuing their more capital-intensive processes and specializing in labor-intensive fragments.

There is also at least one other possibility that should be mentioned. Suppose that, even prior to trade, firms in an industry produce diverse products with at least somewhat different factor intensities for each. These may be differentiated versions of the same product, or they may be distinctly different products that just happen to be grouped into the same industrial classification. In either case, trade will occur along H-O lines, but it will appear as *intra*-industry trade due to the particular grouping of products into industries. That is, as firms producing the more capital-intensive goods within each industry shut down (in a labor abundant country), each country will continue to produce and export from within both industries, from their country's respective end of the factor intensity spectrum, and they will import products from the other end. This will show up as intra-industry trade.

Once again, however, even though this is H-O trade, the factor intensities of the industries will appear to move in the wrong direction. That is, each industry in a labor abundant country will become more labor intensive, as the more capital-intensive product lines within the industry are shut down. It will be difficult to distinguish this phenomenon from that of fragmentation described above.

However, it seems most likely that this last story, if it occurred, would happen across firms rather than within them. That is, an industry would consist of diverse firms, each producing different goods, in fact, with different factor ratios. The story would have the industry becoming more labor intensive, but not the individual firms. If, on the other

both could be, say, more labor intensive.

hand, firms – or especially individual plants – become more labor intensive in a labor-abundant country, then one might reasonably presume that there has been fragmentation. The table below summarizes predictions of the H-O model and the fragmentation theory for the directions of change of capital-labor ratios at the plant and industry levels after trade liberalization.

	H-O inter	*H-O intra*	*Fragmentation*
Industry-level	$\Delta(K/L) > 0$	$\Delta(K/L) < 0$	$\Delta(K/L) < 0$
Plant-level	$\Delta(K/L) > 0$	$\Delta(K/L) > 0$	$\Delta(K/L) < 0$

This bit of theory, then, motivates an empirical study of how factor intensities of plants, firms, and industries change over the course of liberalization in a developing country. Where we find that capital-labor ratios of plants become smaller with trade liberalization, that suggests that fragmentation is occurring. Where we find that capital-labor ratios become larger in plants, but smaller in industries, that suggests that more conventional H-O trade is happening, but that it is happening within industries as they are defined in the data. Finally, if capital-labor ratios are rising even in industries, then we have evidence for H-O inter-industry trade.

Complicating these observations will be changes in technology. The same data that we would use for these measurements are also often used to search for evidence of technological change. If total factor productivities (TFPs) are rising over time along with (and perhaps even because of) trade liberalization, then we must admit the possibility of production functions that are also shifting over time. And if they shift, they could easily change their factor intensities. With arbitrary changes of that sort allowed, no observation on factor intensities can tell us anything for sure about specialization and fragmentation. However, if we are willing to make some assumptions about the nature of any technological change that may occur, then inferences are still possible.

Most simply, suppose that any technological change is necessarily Hicks-neutral. Then technology does *not* change factor intensities, and our arguments go through unscathed. Or, perhaps more plausibly, suppose that technological progress, when it occurs in a developing country, can be assumed to be labor saving. This might be true, but not because that is the kind of technological progress that such countries most need, since that is probably not the case. But it may well be true because new technologies tend to be imported from the developed world, where that is the case. Or one could even argue, we suppose, that technological progress is by its nature labor saving, since it so often tends to involve new forms of capital equipment that either does the work of man or extends man's capacities.

Whatever the reason, if technological progress is labor saving, then if we find capital-labor ratios rising along with trade, we will not be able to distinguish whether this is the result of technology or of factor substitution in response to factor prices and trade. But if we find the opposite – that capital-labor ratios are falling within industries or firms – then we can only suppose that they would have fallen even more without the influence of technology. Therefore if we do observe that, then we can safely conclude that our stories above of specializing either within industries or within firms may plausibly be correct.

3. Data, and Trade Liberalization in Chile

3.1. Trade liberalization in Chile [3]

Chile implemented a large liberalization program during the period of 1974 to 1979. This liberalization included comprehensive restructuring of the economy involving a dramatic reduction and simplification of its trade barriers, reforms of financial markets and labor markets, privatization of government owned firms and relaxation of government price controls. As for trade, quantitative trade restrictions were removed, in addition to huge tariff reductions from 94 percent on average in December 1973 to a uniform 10 percent by June 1979.[4] Table 1 provides the itinerary of import tariff reductions over the period of 1973-91. Table 4 (below) will show that effective rates of protection in manufacturing sectors averaged over 150 percent in 1974, and were drastically reduced to 13.6 percent in 1979 when the first liberalization phase was completed in the middle of the year.

The next period (1979-1982) was characterized by a significant degree of real exchange rate overvaluation as reported in Table 2. Then a temporary reversal phase followed, due to a balance of payments crisis. In the period of 1982-1983, Chile experienced a severe recession and responded with increased tariff protection. Tariffs were raised starting March of 1983 and reached as high as a uniform 35 percent in late 1984. But the tariff hikes were short-lived, and Chile quickly started to reduce the tariff rates starting in early 1985. The tariff rates were reduced back to a uniform 11 percent by June 1991. During the reversal period, the real exchange rate depreciated, reversing the

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[3] This subsection draws heavily on Edwards and Lederman (1998). See their section II for detailed description of trade liberalization in Chile from 1974–1990s.
[4] This uniform 10 percent tariff was applied to all items except automobiles.

overvaluation from the earlier stage as can be seen in Table 2. Despite the reversal period, Chile maintained a strong commitment to unilateral trade liberalization from 1974 through 1991.

The unemployment rates are reported for the nation as a whole, and for the manufacturing sector only, in Table 2. The unemployment rates for the manufacturing sector only are those in the Greater Santiago area. Since all the plants of the data are in the manufacturing sector, the unemployment rates for the manufacturing sector would capture effects of macroeconomic changes on these plants better than those for the nation as a whole. A comparison between the unemployment rates for the manufacturing sector and those for the nation as a whole reveals that the effect of the 1982-83 recession lasted longer for the manufacturing sector than for the other sectors. The unemployment rates for the manufacturing sector were substantially higher than the nation-wide unemployment rates. At least six percentage points of discrepancy between the two unemployment rates can be observed during the period of 1982-84.

3.2. Factor intensities in the Chilean manufacturing sector

Chile provides an interesting set of data to implement an empirical study on the fragmentation theory through the dynamics of capital-labor ratios employed by individual plants after the dramatic trade liberalization. The liberalization measures were huge in magnitude and comprehensive, and trade liberalization took place intensively in a relatively short period of time. Unbalanced plant-level panel data (including plants that enter and exit during the sample period) on the Chilean manufacturing sector are used.

The data set consists of all manufacturing plants of Chile with a minimum of ten employees over the period 1979 through 1986.

For the measure of the capital stock, two sets of net capital stocks are available in the data set, one in 1980 constant prices, and one in 1981 constant prices.[5] A perpetual inventory method was used for construction of the capital stock series. Since capital stock series for plants were constructed using 1980 if both 1980 and 1981 values were available, we use 1980 net capital stocks as our capital variables.[6] Combined with the lack of data on hours worked for individual plants, the fact that we use the capital stock rather than its flow leads us to use the average number of workers as a consistent labor variable. The capital-labor ratio is equivalent to capital stock per worker.

Table 3 reports the data on capital, labor, and the capital-labor ratios for each year. Large standard deviations of capital-labor ratios in each year suggest a great deal of plant-level heterogeneity within the industry, which supports our model assumptions of the co-existence of firms producing different products or at least differentiated products.[7] Table 3 shows that the average capital-labor ratio increased substantially in 1982 when Chile experienced a severe recession with an unemployment rate of 26.7 per cent in the manufacturing sector. Since then, the average ratio has continuously dropped, to 444.5 by 1986.

[5] For the capital stock formation, Liu (1993) used a perpetual inventory method based on balance sheet information of plants. Since the balance sheet information was only available for the plants in 1980 and 1981, capital stocks were constructed based on the book values of those two years. Different economic depreciation rates were applied for different types of capital stocks. See Liu (1993) for the details.

[6] We lose observations for which the 1980 net capital stock values are missing. We could have included a part of these plants by using their 1981 stock values. But we chose not to include them for the consistency of the variable across plants rather than merely increasing observations. We also chose net capital, which was adjusted for depreciation, over gross capital.

[7] While Table 3 shows this overwhelming standard deviations only for manufacturing sector, we find the same evidence in various industries within manufacturing (not reported here).

The simple data of Table 3 seem to reflect the macroeconomic shocks that were observed. Therefore, it is essential to separate the effects of macroeconomic fluctuation on plant-level factor intensities from effects of trade liberalization. This will be discussed later in the estimation. Aside from the macroeconomic fluctuation issue, there are two other factors that argue for a long-term comparison. First, as discussed above, Chile implemented a trade liberalization program that was huge in terms of its magnitude and intensity, and hence its impact must have lasted through most of the 1980s. Second, changes in the production structure would not occur instantly. Especially if a structural shift involves fragmentation, it will require far more than just employing relatively more labor or capital for production. The change might involve dropping some production lines and expanding others. For some plants, this could require switching from one production line to another, even though they could be simply different stages for the same product.

Since our primary concern lies in the structural shift caused by the huge trade liberalization, and this kind of structural change would not occur instantaneously, a long-term comparison might be worthwhile. We can also observe huge variation of effective rates of protection across industries before 1979, as reported in Table 4. For the rubber industry, for example, the effective rate of protection in 1974 was relatively low at 49% while the petroleum and coal industry shows a drastic reduction from 265% in 1974 to 13% in 1979. The difference of effective rates of protection for the industry between 1974 and 1979 can be used as a measure of the degree of trade liberalization in the industry. As for the plant-level capital-labor ratio, we can use the difference of the ratio for the plant between 1986 and 1979 of our sample period.[8]

[8] The long term difference analysis does not provide any significant results. The results are not reported in this version of paper.

The gross value of output measured in 1980 constant prices, which includes all kinds of sales net of inventory changes, will be used for plant-level output in estimation. 3-digit ISIC industry-level data for an extended sample period (1973-92) are obtained from UNIDO and Summers and Heston's data set. Industry-level capital stocks are constructed using the perpetual inventory method.

4. Estimation

4.1. Empirical model

One can expect that an individual plant might change its factor intensity of production when it needs to change the level of output, since labor input can be more quickly adjusted than the capital stock. In the same manner, the capital-labor ratio of a plant can also be changed in response to some macroeconomic shocks. In section 2, we have already discussed how trade liberalization can affect plant-level capital-labor ratios. Combining all these effects, we can express the change of the capital-labor ratio of a plant as a function of the change in its level of output, some macroeconomic shocks that affect an individual plant's choice of input employment, and the trade liberalization effect:

$$\Delta k_{it} = \mathrm{F}(\Delta Y_{it}, \Delta \mathbf{V_t} \,;\, TL) \tag{1}$$

where k_{it} and Y_{it} are capital-labor ratio and output of plant i at time t, respectively, and $\mathbf{V_t}$ is a set of time-varying macroeconomic variables that are exogenous to plants such as unemployment rates and real exchange rates. TL represents the effects stemming from the trade liberalization program that was mostly completed by 1979, the beginning year of our plant-level data. Despite some macroeconomic fluctuations during the sample period, the Chilean government firmly committed to its original trade liberalization program and hence liberalization measures were maintained basically stable.[9] Therefore, we can plausibly suppose that trade liberalization effects have been persistent over the sample period.

The data prevent us from comparing plant-level factor intensities before and after trade liberalization. Nevertheless, we can still see whether firms follow Heckscher-Ohlin or fragmentation predictions in their structural changes subsequent to trade liberalization. This is possible by investigating the dynamics of plant-level factor intensities, because the two theories predict changes in opposite directions for capital-labor ratios at the plant level.

However, there are at least two factors that would complicate our empirical investigation. The first and most conflicting source comes from the 1982-83 recession. The recession would bring another difficult task for the firms that were already struggling to adjust to the huge trade liberalization. It also caused a setback in terms of trade liberalization in the form of the bouncing back of tariff rates. Since these macroeconomic shocks are only time-varying, and hence would affect all the plants uniformly, it is necessary to separate the effects of macroeconomic fluctuations on the plant-level capital-labor ratio from trade liberalization effects. The other complicating factor is unobserved productivity shocks, which we discussed theoretically in section 2. These

[9] Although the average tariff increased up to thirty-five per cent at one point during the sample period, this lasted for less than six months. Moreover, this temporary tariff hike was small relative to the tariff reduction implemented in the original trade liberalization program.

empirical problems and their resolution along with some other empirical issues will be addressed later in section 4.2.

In order to capture the trade liberalization effects apart from macroeconomic shocks, we conduct the estimation in two stages. The first stage regression equation, which can be derived from equation (1), is as follows:

$$\Delta k_{it} = \beta_1 \Delta Y_{it} + \beta_{2t} + \varepsilon_{it} \tag{2}$$

where k_{it} and Y_{it} are capital-labor ratio and output of plant *i* at time *t*, respectively, expressed in logarithms. β_{2t} is a coefficient of a dummy variable for time *t*, and ε_{it} is an i.i.d. random error term. The disturbance term ε_{it} involves unobserved productivity shocks. The dependent variable, Δk_{it}, is the growth rate of the capital-labor ratio. The time dummy coefficient, β_{2t}, captures the structural changes caused by trade liberalization as well as year-specific macroeconomic shocks at time t. By estimating β_{2t} in the first stage, we can construct a time series of the growth of the plant-level capital-labor ratio.

In the second stage, we regress the constructed time series of $\hat{\beta}_{2t}$ on macroeconomic variables. The second stage regression involves time-series variables only and can be written as

$$\hat{\boldsymbol{\beta}}_2 = \Delta \mathbf{V} \boldsymbol{\gamma} + \boldsymbol{\nu} \tag{3}$$

where $\hat{\boldsymbol{\beta}}_2$ is a $(\mathrm{T} \times 1)$ vector of the constructed time-series, $\Delta\mathbf{V}$ is a $(\mathrm{T} \times \mathrm{M})$ matrix of macroeconomic variables expressed in differences, $\boldsymbol{\gamma}$ is a $(\mathrm{M} \times 1)$ vector of coefficients, and $\boldsymbol{\nu}$ is a $(\mathrm{T} \times 1)$ vector of error terms. T represents the number of years and M is the number of macroeconomic variables.

We can obtain time-series estimates of that portion of the growth of the capital-labor ratio that can be attributed to trade liberalization from the following equation:

$$\tilde{\boldsymbol{\beta}}_2 = \hat{\boldsymbol{\beta}}_2 - \mathbf{V}\hat{\boldsymbol{\gamma}} \tag{4}$$

where $\hat{\beta}_2$ is a $(\mathrm{T} \times 1)$ vector of the coefficients of dummy variables estimated in the first stage, and $\hat{\gamma}$ is a $(\mathrm{M} \times 1)$ vector of the coefficient estimates of the second stage regression. Thus, a $(\mathrm{T} \times 1)$ vector $\tilde{\beta}_2$ will expose the dynamics of plant-level factor intensity that is induced by trade liberalization separated from concurrent macroeconomic shocks after controlling for output variation in the first stage regression.

4.2. Estimation issues

There are many macroeconomic variables that might cause structural changes in firms. Due to the limited time span of our data, however, we are confined to only a couple of macroeconomic variables in the second stage regression. It is crucial to choose the most significant and representative ones. For the following reasons, we include concurrent tariff rates and unemployment rates of the manufacturing sector in the second stage regression.

The 1982-83 recession is perceived to be the most notable macroeconomic shock over the entire sample period after trade liberalization. The recession must have forced firms to lay off workers, which would raise capital-labor ratios for reasons not related to structural changes following trade liberalization. The coefficient of the unemployment rate will pick up this effect. Table 2 shows visible discrepancy between the unemployment rates for the manufacturing sector and those for the nation as a whole, especially from 1982 through 1990. When the economy moves into a severe recession, the impact of the recession may vary across sectors. In Chile, less than twenty per cent of workers were employed in the manufacturing sector in the 1980s. Since plants in the data are all in the manufacturing sector, the manufacturing-sector-specific unemployment rates are more appropriate to capture this effect than the unemployment rates for the nation as a whole. The unemployment rate for the manufacturing sector in Greater Santiago, which accounts for more than sixty per cent of plants in the manufacturing sector, is used as a proxy for the unemployment rate for the whole manufacturing sector.

The recession was immediately followed by a temporary setback of trade liberalization. The temporary rebound of tariff rates was moderate compared to the initial reduction that was integrated in the trade liberalization program, and it was short lived. Although one can hardly claim that this bump in the transition period would have overturned the massive trade liberalization effects, one can not ignore the impact of this backward step either, since the tariff is one of the most vital ingredients of trade policy. Therefore, we include these temporary and small tariff changes during the sample period in our estimation. Again, the purpose of having the tariff change variable in the regression is not because we are interested in the relationship between the small changes of tariff and the dependent variable, but rather to control for the noise created by the temporary setback in the middle of the restructuring process after a huge liberalization program was set in.[10] By including both unemployment and tariff rates in the second stage, we can estimate the effects of macroeconomic shocks over the sample period, effects that will later be disconnected from trade liberalization effects in equation (4). In the estimation, equation (3) for each year t can be rewritten as

$$\hat{\beta}_{2t} = \gamma_1 + \gamma_2 \Delta unempm_t + \gamma_3 \Delta trf_t + \nu_t \tag{5}$$

where $unempm_t$ is the unemployment rate of the manufacturing sector in year t and trf_t is the average tariff rate for that year. Both are expressed in differences to be consistent with the dependent variable that is constructed in differences in the first stage regression.

If we believe that technology progresses over time, we can reasonably expect technological progress over time in Chile as well, especially after such a huge trade liberalization. Trade liberalization might cause plant-level productivity improvement either through a rationalization process or simply because of access to better technology through now relatively cheaper imported capital. This would then cast doubt on the independence between regressors and the disturbance term in the estimation of equation (2). Including productivity measures in the regression would be a natural candidate for resolving this problem. However, productivities are not observed and hence should be estimated, or we might use instrumental variables that are closely related with the regressors but not with the error term. Estimated productivity measures have been under

[10] It turns out as discussed in the next section that the coefficient of tariff changes is not statistically

debate because of their possible biases depending on methodologies, and hence they can create other problems. Instrumental variables (IV) estimation might be useful, but it might also create more serious problems such as increasing the bias ratio of IV and OLS estimators if we cannot find good instruments, which is most likely the case.[11]

Recent literature on unobserved – to econometricians but known to plant managers – productivity measures using a semiparametric approach can provide more precisely estimated productivity measures.[12] If technology shocks are Hicks-neutral or labor-saving as discussed in section 2, however, the direction of the bias can be plausibly predicted. With information on the direction of the bias, the attenuation inconsistency can be a point of strengthening our results, rather than a problem.[13] We will revisit this issue with the estimation results in the following section.

Various plant sizes in the data would create a heteroskedasticity problem in the first stage regression. In order to address this problem we use White-corrected OLS with robust standard errors. In the second stage regression, where we have time series data, an autocorrelation problem is reasonably suspected. The most common autocorrelated error process is the first-order autoregressive process. Assuming that error terms in the second stage regression follow an AR(1) process, the Prais-Winsten estimator is used to correct the autocorrelation problem.

5. Estimation results

5.1. Plant-level analysis

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significant.

[11] See Bound, Jaeger, and Baker (1995) for problems with weak IV estimation.

The first stage estimation results are reported in Table 5. Since we are using panel data, we estimate equation (2) using an OLS model, a fixed-effects model, and a random-effects model.[14] The first column of Table 5 shows the OLS results of equation (2) while the fixed-effects and random-effects regression results are reported in the second and third columns, respectively. The results are not significantly different across OLS, fixed-effects regression, and random-effects regression. The coefficient of the output variable is about −0.13 and statistically very significant in all three regressions, which implies that an individual plant reduces its capital-labor ratio about thirteen hundredths of a per cent for a one percent increase of output. This negative sign of the coefficient of the output variable and its small magnitude are what we expected. Because of the relative flexibility of labor input, firms may be able to increase or decrease output without changing capital stocks.

The dummy variable for 1980 is excluded in estimation. The coefficients of year dummy variables are therefore measures of the growth of capital-labor ratios relative to 1980. These estimates should be interpreted cautiously, since they include macroeconomic variation effects in addition to trade liberalization effects. After controlling for output variation effects, the growth rate of the capital-labor ratio in 1982 is 2.9 per cent higher than in 1980, partially reflecting a severe recession in Chile. Since this coefficient also contains trade liberalization effects, and if plants were following the prediction of fragmentation theory, the effect of the recession on the change in capital-labor ratio should have been higher than 2.9 per cent in 1982. After 1982, the growth

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[12] See Olley and Pakes (1996) for the methodology. Pavcnik (2002) estimates Chilean plant-level productivity following Olley and Pakes (1996).

[13] The effect of biasing the coefficient toward zero is called attenuation. Greene (1997).

rates of the capital-labor ratio are at least five per cent lower than in 1980. The three regressions do not show any systematic differences in their coefficients. In particular, the coefficients of the random-effects model are almost identical to those of OLS. We will proceed to the second stage estimation and construct the time series of the growth of the capital-labor ratio using the coefficients of the first stage OLS regression.

Table 6 shows the second stage estimation results of equation (5). Prais-Winsten estimation results are reported along with OLS regression results. The autocorrelation parameter, rho(ρ) is 0.72, and the transformed Durbin-Watson statistic is 1.9389 suggesting no autocorrelation after correction was made.[15] In both OLS and Prais-Winsten estimation, effects of tariff changes on change in the capital-labor ratio are statistically insignificant. A possible reason for this insignificant coefficient of tariff changes can be attributed to no variation of tariff at 10.1 percent during1980-82. The coefficient of the unemployment rate is positive as expected and statistically significant.

Based on the two regressions reported in Table 6, we calculate the corresponding values of $\tilde{\beta}_{2t}$, which represents effects of trade liberalization on the growth of plant-level capital-labor ratios for time t. These trade liberalization effects, extracted from the constructed time series using equation (4), are shown in Table 7 along with the constructed time series, $\hat{\beta}_{2t}$. $\hat{\boldsymbol{\beta}}_2$ is the vector of the estimated coefficients of year dummy variables in the first stage regression, and represents year-specific effects on the growth of plant-level capital-labor ratios reflecting both trade liberalization effects and macroeconomic business cycle effects. From the values of $\hat{\boldsymbol{\beta}}_2$, we find that the plant-level

[14] Breusch and Pagan Lagrangian multiplier test and Hausman specification test find no systematic differences between fixed-effect and random-effect GLS regression model.
[15] The original Durbin-Watson statistic is 0.7389.

capital-labor ratio increased for the first three years of the sample period and then decreased continuously after 1983. They are all statistically very significant except for 1980. However, we can not determine how much of the change in the capital-labor ratio can be attributed to trade liberalization from these values of $\hat{\boldsymbol{\beta}}_2$ because they also include some macroeconomic business cycle effects during this period.

Column (3) of Table 7 reports the values of $\tilde{\beta}_{2t}$, which show the effects of trade liberalization on the growth of plant-level capital-labor ratios. For the first half of the sample period, the initial two years show positive, but not significant, growth of the capital-labor ratio. The negative values (although statistically insignificant) of $\tilde{\beta}_{2t}$ for the next two years suggest that there was a turnaround in the growth rate of plant-level capital-labor ratios in that period. The values of $\tilde{\beta}_{2t}$ for the bottom half of the sample period indicate very significant decrease in capital-labor ratios at the plant-level. During this period individual plants reduced the capital-labor ratio about five percent annually in response to trade liberalization according to these values.

The results reported in Table 7 seem to be in favor of fragmentation rather than the H-O model. Since fragmentation requires some structural adjustments in the production process, it might naturally take some time to see significant changes in capital-labor ratios following trade liberalization. Using the same data set, Pavcnik (2002) investigated the effects of liberalized trade on plant productivity and she also suggested that plants might have responded to the changes in trade regime with some delay, perhaps due to the sustainability of the regime change. Furthermore, if we consider the attenuation bias caused by unobserved productivity improvement as we discussed in section 4.2, the results can be interpreted to be supporting the fragmentation theory more strongly. The positive attenuation bias suggests that true values of those $\widetilde{\beta}_{2t}$ must be bigger in absolute terms for negative values, and smaller for the positive values than those reported in Table 7.[16]

5.2. Estimation results for industry-level factor intensity

Table 8 shows OLS regression results for different time periods using industry-level data. Since industry-level data are available for a more extended sample period than plant-level data, we are able to split the sample into three periods. The first period (1973-78) represents the active reform period. During this period, tariffs were steadily reduced, and other measures were continuously liberalized. The second period (1979-86) exactly overlaps with the sample period of our plant-level panel data. During this period Chile experienced volatile macroeconomic fluctuations. The third period (1987-92) is characterized by continuous efforts of liberalization after a setback in the second period.

In this industry-level analysis, we use the change of the industry-level capital-labor ratios in logarithms as the dependent variable. Instead of the unemployment rate, we include the change in industry-level output as a regressor in order to better capture the business cycle effects at the industry level.

Column (1) reports the estimation results for the entire sample period. Period dummy variables are also included to see the growth of capital-labor ratios at the industry level.

[16] The covariance of technological progress and change in output (ΔY_{it}) or a time variable would be positive according to the discussion in section 2, i.e., Cov (ε_{it} , ΔY_{it}) > 0 , and Cov (ε_{it} , time) > 0, particularly for the plants that survive. If technological progress is Hicks-neutral, its correlation with the dependent variable, change of the capital-labor ratio will be zero, and hence the problem will disappear. Or, if it is labor-saving, then the correlation will be positive. This assures that the bias will be positive, combined with the positive covariance of the disturbance term and the regressors of interest.

The first year is the excluded period. The coefficients of period dummy variables indicate that the growth rates of capital-labor ratios for the second and third periods are significantly lower than in the first period. The effect of output changes is negative but not statistically significant. The coefficient of real exchange rates is negative and significant. Levinsohn (1999) also found similarly strong job growth rate responses to real exchange rate changes. Since an increase of real exchange rate implies depreciation of the currency, about one percent depreciation relative to 1977 results in a decrease of four tenths of a per cent in the industry-level capital-labor ratio. The coefficient of the tariff is −0.0269 and statistically significant, implying that a one percent tariff increase reduces capital-labor ratios by 2.7 per cent.

Columns (2)-(4) report the regression results for each sub-sample period. The first period does not show any statistically significant result.[17] This suggests that the variance across industries during this period was huge and any statistical inference from the estimation would not be appropriate. What is interesting here is the turnaround of the sign of tariff coefficients from the second period to the third period. In the second period, which is the sample period for the plant-level data, the average tariff was raised a little bit because of the severe recession, and then liberalized again later. Nonparametric analysis shows overall declining capital-labor ratios at the industry level. The negative coefficient of the tariff reflects this relationship. However, the tariff coefficient becomes positive for the third period as reported in column (4). While the direct effect of tariff changes on the growth of capital-labor ratios at the industry level may vary across periods, again our primary interest is the effect of the drastic trade liberalization completed by 1979 on the growth of capital-labor ratios, which are reported as periods in column (1) after controlling for some macroeconomic fluctuations during the period. Together with this industry-level analysis, the results of plant-level data imply that Chilean plants seem to have experienced structural change as suggested by the fragmentation theory.

6. Conclusion

In this paper, we have examined structural changes in response to trade liberalization. We first introduced contrasting theoretical implications of trade theories for factor intensities following trade liberalization. The traditional Heckscher-Ohlin model predicts that industries and plants in a labor abundant country will raise capital-labor ratios after liberalization. In contrast, the fragmentation theory, an otherwise similar model, predicts the opposite. If we investigated industry-level data alone, the results could be misleading because H-O type intraindustry specialization also predicts a decrease in capital-labor ratios. At the plant-level, however, theoretical implications are clear about the structural change without this complication: an increase in capital-labor ratios according to H-O and a decrease for fragmentation.

We investigated the effects of trade liberalization on the growth of capital-labor ratios by using Chilean plant-level data as well as industry-level data. Overall, capital-labor ratios were falling both at the industry level and at the plant level following trade liberalization. At the industry level, the periods after trade liberalization clearly exhibit a significant decrease in capital-labor ratios compared to the period before the liberalization after controlling for macroeconomic fluctuations. At the plant level, we examined yearly changes of capital-labor ratios after controlling for macroeconomic

[17] F-test indicates that coefficients of the regression for this period are jointly insignificant.

fluctuations. We found an eventually decreasing trend of capital-labor ratios except for the first a few years immediately following trade liberalization. This delayed pattern of capital-labor ratios presents evidence for the fragmentation theory, since fragmentation requires plants to go through some structural changes in the production process. Furthermore, this pattern of structural change that we found is similar to the findings of other studies, such as Pavcnik (2002) and Levinsohn (1999), that used the same data set to investigate different sets of structural changes following trade liberalization in Chile.

While our empirical results seem to support the fragmentation theory rather than the traditional H-O model, we nevertheless acknowledge that the evidence is not resoundingly strong because of the limited availability of plant-level data only after trade liberalization and some concerns with respect to macroeconomic fluctuations during the sample period. All in all, this paper is a first step toward exploring the role that fragmentation induced by trade liberalization may play. More studies are needed to examine the pattern of structural changes associated with trade liberalization and hence to improve our understanding of it.

References

Bosworth, B.P., R. Dornbusch, and R. Labán (1994), *The Chilean Economy: Policy Lessons and Challenges*, Washington, D.C: The Brookings Institution.

Bound, J. and D. A. Jaeger, and R. M. Baker (1995), Problems with Instrumental Variables Estimation When the Correlation between the Instruments and the Endogenous Explanatory Variable is Weak, *Journal of the American Statistical Association*, 90(430), pp. 443-50.

Corbo, V., and S. Fischer (1994), Lessons from the Chilean Stabilization and Recovery, in B. P. Bosworth, R. Dornbusch, and R. Labán (eds.) *The Chilean Economy: Policy Lessons and Challenges*, Washington, D.C: The Brookings Institution.

Deardorff, A. V. (2001a), "Fragmentation across Cones," in Sven W. Arndt and Henryk Kierzkowski, eds., *Fragmentation: New Production Patterns in the World Economy*, Oxford University Press, pp. 35-51.

Deardorff, A. V. (2001b), "Fragmentation in Simple Trade Models," *North American Journal of Economics and Finance* 12, (July), pp. 121-137.

Dornbusch, R. and S. Edwards (1994), Exchange Rate Policy and Trade Strategy, in B. P. Bosworth, R. Dornbusch, and R. Labán (eds.) *The Chilean Economy: Policy Lessons and Challenges*, Washington, D.C: The Brookings Institution.

Economist (Oct. 3, 1998), A Survey of World Trade

Edwards, S., and A. C. Edwards (1987), *Monetarism and Liberalization: The Chilean Experiment*, Cambridge, MA: Ballinger.

Edwards, S. and D. Lederman (1998), The Political Economy of Unilateral Trade Liberalization: The Case of Chile, *NBER Working Paper* 6510.

Feenstra, R. C. and G. H. Hanson (1996), Globalization, Outsourcing, and Wage Inequality, *American Economic Review*, 86, May, pp. 240-45.

Greene, W.H. (1997), Econometric Analysis, 3rd ed. Upper Saddle River, NJ: Prentice Hall.

Grossman, G. M. (1992), *Imperfect Competition and International Trade*, Cambridge, MA: MIT Press.

Hummels, D. (2001), Time as a trade Barrier, mimeo, Purdue University.

Jones, R. W. and H. Kierzkowski (2001), "Globalization and the Consequences of International Fragmentation," in R. Dornbusch, G. Galvo and M. Obsfeld, eds., Money, Factor Mobility and Trade: Festchrift in Honor of Robert A. Mundell, MIT Press, Cambridge, Massachusetts.

Levinsohn, J. (1999), Employment Responses to International Liberalization in Chile, *Journal of International Economics*, 47, pp. 321-344.

Liu, L. (1991), *Entry-Exit and Productivity Changes: An Empirical Analysis of Efficiency Frontiers*, Ph. D. thesis, University of Michigan.

Liu, L. (1993), Entry-Exit, Learning and Productivity Change: Evidence from Chile, *Journal of Development Economics*, 42, pp. 217-242.

Olley, S. and Pakes, A. (1996), The Dynamics of Productivity in the Telecommunications Equipment Industry, *Econometrica* 64, pp. 1263-1297.

Pavcnik, N. (2002), Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants, *The Review of Economic Studies* 69, pp. 245-76.

UNCTAD (1992), *Trade Liberalization in Chile: Experiences and Prospects*, Trade Policy Series No. 1, New York: United Nations.

UN (1982-96), *Economic survey of Latin America and the Caribbean*, Economic Commission for Latin America and the Caribbean, Santiago, Chile: United Nations.

Wacziarg, R. and J. S. Wallack (2004), Trade Liberalization and International Labor Movements, *Journal of International Economics*, 64, pp. 411-439.

Table 1. Itinerary of Import Tariff Reductions: 1973–91

Date (mm/dd/yy)	Maximum Tariff	Portion of Items Subject to Maximum Tariff (%)	Tariff Mode	Average Tariff
12/31/73	220	8.0	90	94.0
03/01/74	200	8.2	80	90.0
03/27/74	160	17.1	70	80.0
06/05/74	140	14.4	60	67.0
01/16/75	120	8.2	55	52.0
08/13/75	90	1.6	40	44.0
02/09/76	80	0.5	35	38.0
06/07/76	65	0.5	30	33.0
12/23/76	65	0.5	20	27.0
01/08/77	55	0.5	20	24.0
05/02/77	45	0.6	20	22.4
08/29/77	35	1.6	20	19.8
12/03/77	25	22.9	15	15.7
06/../78[a]	20	21.6	10	13.9
06/../79[a]	10	99.5	10	10.1
03/23/83	20	99.5	20	20.0
09/22/84	35	99.5	35	35.0
03/01/85	30	99.5	30	30.0
06/29/85	20	99.5	20	22.0
01/05/88	15	99.5	15	15.0
06/91	11	99.5	11	11.0

Source: Ffrench-Davis (1980 [1986]) and Saez, et al. (1995) cited in Edwards and Lederman (1998).

Notes: Tariffs are nominal tariffs in per cent of c.i.f. value of imports.

a During 1978 and the first half of 1979, the tariff schedule was reduced linearly.

Table 2. Average tariff, real exchange rate and unemployment rates (in percentage)

Year	*Average tariff*[1]	*Real exchange rate*[2]	*Unemployment rate*[3]	*Unemployment rate in manufacturing*[4]
1973	94.0[a]	74.4	5.0	3.5
1974	75.6	122.7	9.5	7.6
1975	49.3	147.1	14.8	14.8
1976	35.6	124.1	12.7	15.5
1977	24.3	100.0	11.8	11.8
1978	14.8	111.4	14.2	11.8
1979	12.1	112.2	13.6	13.1
1980	10.1	97.2	10.4	11.9
1981	10.1	84.5	11.3	11.8
1982	10.1	94.2	19.6	26.7
1983	17.9	113.1	14.6	25.9
1984	24.4	118.2	13.9	19.5
1985	25.8	145.2	12.0	14.9
1986	20.1	159.7	8.8	12.9
1987	20.0	166.6	7.9	11.0
1988	15.1	177.6	6.3	8.9
1989	15.1	173.5	5.3	8.0
1990	15.1	180.1	5.7	9.4
1991	12.9	169.9	5.5	6.7
1992	11.0	156.7	4.5	5.4

Sources: Central Bank of Chile and CIEPLAN (1990) cited in Corbo and Fischer (1994) and UNCTAD (1992).

Notes:

1 Annual average tariff, excluding preferential treatment in free zones and integration schemes. Percentage of c.i.f. value of imports, nominal tariffs.

2 An index with 1977 as a base year (=100). An increase in the real exchange rate indicates a real depreciation of the domestic currency.

3 Percent of labor force.

4 Unemployment rates for manufacturing sector in Greater Santiago according to data from the Department of Economics of the University of Chile reported in UN (1982-96).

a Corresponds to December 1973.

Table 3. Data on Capital, Labor and K/L ratio in Manufacturing sector

(in 1980 constant prices)

		Capital	Labor[a]	K/L ratio	Growth rate of K/L ratio
1979	mean	39212.9	54.2	428.5	
	st.dev.	182897.5	108.3	903.2	—
	obs.	3606	3606	3606	
1980	mean	39419.8	55.2	410.1	.0052
	st.dev.	195494.2	113.3	924.8	.4483
	obs.	3814	3814	3814	3605
1981	mean	42186.9	55.1	421.5	.0072
	st.dev.	206434.7	108.0	1063.2	.3468
	obs.	3556	3556	3556	3547
1982	mean	45879.2	49.1	511.6	.07083
	st.dev.	226227.2	94.0	1472.1	.3415
	obs.	3217	3217	3217	3212
1983	mean	49163.1	51.7	497.2	-.03492
	st.dev.	254755.0	97.5	1352.4	.3219
	obs.	2833	2833	2833	2832
1984	mean	51405.2	57.2	468.1	-.09261
	st.dev.	258588.0	102.8	1173.4	.2893
	obs.	2633	2633	2633	2632
1985	mean	52545.9	61.8	452.5	-.0656
	st.dev.	262434.0	109.4	1258.4	.3104
	obs.	2520	2520	2520	2519
1986	mean	56057.9	69.9	444.5	-.0693
	st.dev.	267629.6	118.0	1297.3	.3103
	obs.	2330	2330	2330	2328
Total	mean	45983.9	56.1	451.7	-.0192
	st.dev.	228831.6	106.7	1176.7	.3520
	obs.	24509	24509	24509	20675

Note: The figures are based on the plants with non-missing capital and labor data.

a Average number of workers

Table 4. Effective rates of protection in Chile: 1974-79 (in percentages)

Sector	1974	1976	1978	1979
Foodstuff	161	48	16	12
Beverages	203	47	19	13
Tobacco	114	29	11	11
Textiles	239	74	28	14
Footwear	264	71	27	14
Timber products	157	45	16	15
Furniture	95	28	11	11
Paper products	184	62	22	17
Publishing	140	40	20	12
Leather products	181	46	21	13
Rubber products	49	54	26	15
Chemicals	80	45	16	13
Petroleum and coal	265	17	12	13
Nonmetallic minerals	128	55	20	14
Basic metals	127	64	25	17
Metallic industries	147	77	27	15
Nonelectrical machinery	96	58	19	13
Electrical machinery	96	58	19	13
Average	151.4	51.0	19.7	13.6
Standard deviation	60.4	15.7	5.3	1.7

Source: Corbo and Sanchez (1985) cited in Liu (1991).

Table 5. Estimates of the first stage regression using equation (2)

(Dependent variable is the growth rate of the plant-level capital-labor ratio.)

	(1) OLS	*(2) Fixed Effects*	*(3) Random Effects*
Dlgvo	-.1301***	-.1296***	-.1302***
	(.0082)	(.0058)	(.0053)
1981	.0042	.0025	.0040
	(.0092)	(.0082)	(.0078)
1982	.0294***	.0267***	.0290***
	(.0092)	(.0087)	(.0082)
1983	-.0511***	-.0575***	-.0524***
	(.0093)	(.0089)	(.0084)
1984	-.0914***	-.1006***	-.0934***
	(.0091)	(.0091)	(.0085)
1985	-.0746***	-.0841***	-.0767***
	(.0094)	(.0092)	(.0086)
1986	-.0617***	-.0723***	-.0640***
	(.0097)	(.0094)	(.0089)
Constant	.0108	.0159***	.0111*
	(.0071)	(.0059)	(.0058)
Observation	20667	20667	20667
R^2	.0492	.0548	.0492

Notes: Dlgvo is first differenced plant-level gross value of output in logarithms. 1980 is the excluded year. Standard errors are in parentheses. *** indicates significance at a 1% level, ** at a 5% level, and * at a 10% level.

Table 6. Estimates of the second stage regression using equation (5)

(Dependent variable is $\hat{\beta}_{2t}$, which is estimated in the first stage.)

	(1) OLS	*(2) Prais*[a]
Δ unempm	.0050*	.0034**
	(.0019)	(.0010)
Δ trf	-.0020	-.0017
	(.0029)	(.0018)
Constant	-.0218	-.0438
	(.0126)	(.0243)
Adj. R^2	.51	.74
Rho (ρ)	—	.7220***
		(.1474)

Notes: Δ unempm and Δ trf are changes of unemployment rates for the manufacturing sector and changes of average tariff rates, respectively. Standard errors are in parentheses. *** indicates significance at a 1% level, ** at a 5% level, and * at a 10% level.

a Prais-Winsten regression. Transformed Durbin-Watson statistic is 1.9389. (Original DW = 0.7389)

Table 7. $\hat{\beta}_{2t}$ and resulting values of $\tilde{\beta}_{2t}$ in equation (4)

	(1) $\hat{\boldsymbol{\beta}}_2$	(2) $\tilde{\boldsymbol{\beta}}_2$ (OLS)	(3) $\tilde{\boldsymbol{\beta}}_2$ (Prais)
1980	.0108 (.0071)	.0127 (.0094)	**.0116** **(.0080)**
1981	.0150*** (.0058)	.0155* (.0071)	**.0153*** **(.0071)**
1982	.0402*** (.0059)	-.0339 (.0289)	**-.0108** **(.0155)**
1983	-.0403*** (.0059)	-.0207 (.0228)	**-.0247** **(.0152)**
1984	-.0806*** (.0056)	-.0358 (.0210)	**-.0479***** **(.0123)**
1985	-.0638*** (.0061)	-.0381** (.0114)	**-.0457***** **(.0082)**
1986	-.0509*** (.0065)	-.0524** (.0187)	**-.0535***** **(.0134)**

Note: Standard errors are in parentheses. *** indicates significance at a 1% level, ** at a 5% level, and * at a 10% level.

Table 8. Estimates of industry-level data regression

(Dependent variable is the change of industry-level capital-labor ratios in logarithms.)

	(1) 1973-92	*(2) 1973-78*	*(3) 1979-86*	*(4) 1987-92*
Δln(Output)	-.1142	-.1622	-.2434***	-.2321*
	(.0798)	(.1812)	(.0616)	(.1254)
Δtrf	-.0269***	-.0034*	-.0240***	.0867***
	(.0070)	(.0180)	(.0045)	(.0133)
Δrex	-.0043**	-.0005	-.0066***	-.0218***
	(.0022)	(.0041)	(.0017)	(.0027)
Period_2	-.4898***			
	(.1526)			
Period_3	-.6797***			
	(.1447)			
Constant	.8629***	.7705***	.4099***	.3726***
	(.1533)	(.4673)	(.0274)	(.0470)
Observation	520	129	223	168
R^2	.31	.03	.26	.37

Notes: Output is industry output. trf and rex are tariff and real exchange rates. Period_1 (1973-78) is the excluded period in the column (1). Standard errors are in parentheses. *** indicates significance at a 1% level, ** at a 5% level, and * at a 10% level.

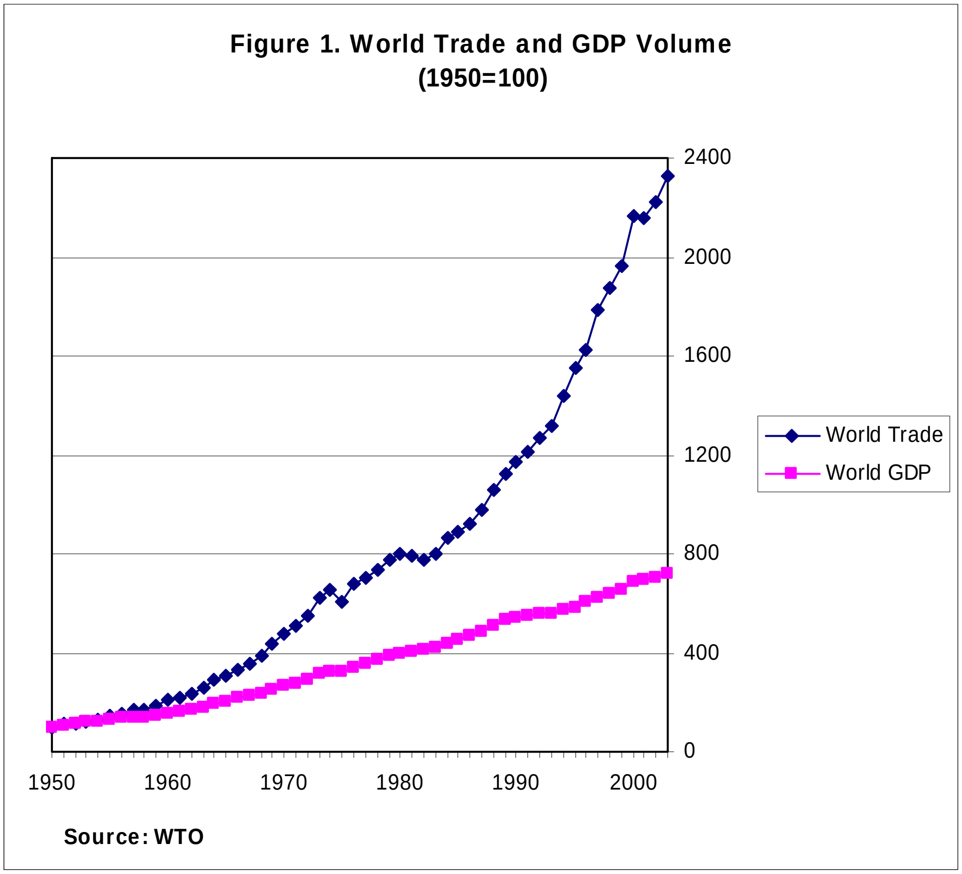
Figure 1. World Trade and GDP Volume
(1950=100)
2400
2000
1600
1200
800
400
0
1950
1960
1970
1980
1990
2000
World Trade
World GDP
Source: WTO