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Productivity and Trade Liberalizations in Canada

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Abstract

I study the evolution of productivity in Canada relative to the United States during two trade liberalization episodes: the 1965 Auto Pact and the 1989 Free Trade Agreement. I find that Canada´s productivity grew more than U.S. productivity in the liberalized sector, which is consistent with the idea that openness increases productivity. This study reveals new evidence of productivity during the Auto Pact. Regarding the Free Trade Agreement, existing studies find that manufacturing productivity grew less in Canada than in the United States following the agreement. I argue that this is due to the use of prices that are not comparable across countries. Once these prices are made comparable, my findings are that manufacturing productivity grew more in Canada than in the U.S. The results of this study suggest there are productivity gains associated with trade liberalization, and models of international trade should account for them.

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1. Introduction

The effects of trade liberalization on economic outcomes are heavily debated in the economic literature, and, while most economists believe that trade liberalization increases productivity, the evidence in favor of this view is, at best, mild. In this paper, I study the behavior of productivity during two episodes of trade liberalization between the United States and Canada: the Auto Pact in 1965 and the Free Trade Agreement between 1989 and 1998. I find that manufacturing productivity grew more in Canada during the liberalization periods; consistent with the idea that trade liberalization fosters growth, since trade should affect more the smaller country.

I start by discussing whether theoretical models of international trade predict gains in productivity. I first show that most common models (i.e. Melitz, 2003, and Eaton and Kortum, 2002) predict no gains in *measured* productivity from a reduction in trade barriers. Next I show that small modifications, such as introducing innovation or variable markups, can account for these gains.

The first agreement I study is the Auto Pact. Signed in 1965, it eliminated tariffs related to automobiles and auto parts. Trade volumes, measured as imports plus exports relative to Canadian output in auto industries, increased by a factor of seven. Canadian automotive productivity grew 22% relative to U.S. from 1965 to 1973. The second agreement is the Free Trade Agreement between the U.S. and Canada. This started in 1989 and gradually eliminated all tariff and non-tariff trade barriers, ending in 1998. Trade volumes increased by over 80 percent, and Canadian manufacturing productivity relative to U.S. grew by 13 percent.

Not much attention has been paid to the Auto Pact, so the results shed light on an episode that is not very well understood. The Free Trade Agreement, on the other hand has been the subject of many studies (Kehoe, 2003, provides a detailed survey). This episode is puzzling because different studies find different results. Trefler (2004) finds significant productivity gains from trade in Canadian industries. Van Ark et al. (2002) find that Canadian manufacturing productivity grew less than U.S. manufacturing productivity.

My results are clearly opposite to Van Ark et al.'s, who show that Canadian productivity fell by 36 percent relative to U.S. The difference arises from two particular industries: computers and semiconductors, which represent less than 5% of manufacturing value added. These are the only industries where productivity growth in the U.S. largely outgrew Canadian productivity. Computers grew by a factor of 210 during the free trade agreement in U.S., and semi-conductors by a factor of 12. The corresponding numbers for Canada are 11 and 2. The reason why these numbers are so much higher in the U.S. is related to the use of widely different price adjustments. In fact, ignoring these industries, Canada gains relative to U.S. close to 17 percent in productivity.

One problem, pointed out by Van Ark et al. (2003), is that the fast change in quality of these sectors during the years of the free trade agreement has made it very hard for the national accounts to come up with reasonable price deflators that can be compared across countries. While both U.S. and Canada use price deflators that adjust for the changing quality, these are not consistent with each other. Using Canadian price deflators to measure real value added in these sectors in both countries, I find that Canada's productivity grew more than United States'.

The fact that trade liberalization implies productivity gains has important policy implications. For once, it compensates for the fact that trade liberalization implies job losses, as found by Trefler

(2004), Kambourov (2009) and Pierce and Schott (2012), among others. If these productivity gains persist, then expanding manufacturing industries might absorb the temporary increase in unemployment. Also, this evidence can also help us understand why some countries seem to grow when they remove trade barriers, as the case of China and South Korea.

2. Measured Productivity and Trade Liberalization in Theory

Recently, a large body of research studies whether trade liberalization increases productivity. Most theoretical frameworks predict that trade liberalization implies welfare gains, but this does not necessarily translate into productivity gains, when productivity is measured as in the national accounts. For example Melitz (2003) and Eaton and Kortum (2002) predict gains in welfare, but not in measured productivity. Rubini (2014), on the other hand, shows that adding innovation into Melitz (2003) as in Atkeson and Burstein (2010) is enough for trade liberalization to account for gains in measured productivity.

Gibson (2006) and Burstein and Cravino (2012) point out that Melitz (2003) does not imply productivity gains from trade. The argument is the following. To measure the increase in productivity from year 0 to year 1, the National Income and Product Accounts (NIPA) first computes current price productivity, and then uses a price deflator to compare periods 0 and 1. Since labor is the only factor of production, current price productivity is

$$Prod_t^c = \frac{\int p_t(\omega) q_t(\omega) d\omega}{\int h_t(\omega) d\omega} \tag{1}$$

where $Prod_t^c$ is productivity in current prices in period t, ω is the name of each good, $p_t(\omega)$ is its price, $q_t(\omega)$ the quantity, and $h_t(\omega)$ is labor employed. Productivity is total revenue divided by the total number of workers (no intermediate goods implies revenue equals value added).

Price is a constant mark-up over marginal cost. If the production function is $q(z, h; \omega) = zh$, with z a technology parameter and h labor, and the wage rate is w, then marginal cost is $c(z; \omega) = w_t/z$ and the price is $p(z; \omega) = \mu w_t/z$, where $\mu > 1$ is the mark-up. The numerator in equation (1) is

$$\int p(\omega) q(\omega) d\omega = \int \left(\frac{\mu w_t}{z}\right) \big(zh(\omega)\big) d\omega = \mu w_t \int h(\omega) d\omega \tag{2}$$

so that $Prod_t = \mu w_t$. Thus, if we compare current price productivity in periods 0 and 1, the ratio is w_1/w_0. But in general we compare constant price productivity. To do this, we use price deflators. There are several options. Here I illustrate how the use of Laspeyres price index works. The Appendix in Rubini (2014) shows that using Paasche pricing or chain weighted prices produces the same result. Constant price productivity using Laspeyres' price deflator is[1]

$$\Delta Prod_{01}^K = \frac{Prod_1^c}{Prod_0^c} \div P_{01} \tag{3}$$

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[1] A problem both in the model and the data is that the set of goods is commonly not the same, and a common basket of goods is used to compute the price deflator. Still, when introducing a good that is only present in one of the compared periods, NIPA guidelines suggest using a "comparable" good in the period where the good is absent.

where k stands for constant price, and P_{01} is the price deflator between periods 0 and 1, defined as

$$P_{01} = \frac{\int p_1(\omega)q_0(\omega)d\omega}{\int p_0(\omega)q_0(\omega)d\omega} = \frac{\mu w_1 \int h_0(\omega)d\omega}{\mu w_0 \int h_0(\omega)d\omega} = \frac{w_1}{w_0} \tag{4}$$

Thus, $\Delta Prod_{01}^{K} = 1$, and there are no productivity gains in Melitz (2003). Notice that Eaton and Kortum (2002) works the same way, except that in their case $\mu = 1$.

Rubini (2014) shows that adding innovation to Melitz can deliver gains in measured productivity. Innovation endogenizes the variable z in the production function, so that we write it now as z_t. The only change with respect to Melitz is the numerator equation (4). Notice

$$\int p_1(\omega)q_0(\omega)d\omega = \int \frac{\mu w_1}{z_1(\omega)} \times z_0(\omega)h_0(\omega)\, d\omega \tag{5}$$

That is, the technology parameters no longer cancel out. While I cannot prove in closed form solution that measured productivity increases, Rubini (2014) shows via a calibrated model that in this setting measured productivity increases. Another way of generating productivity gains from trade is by using models with variable mark-ups, as Bernard et. al. (2002), Melitz and Ottaviano (2008) or McQuoid and Rubini (2015).

3. The Auto Pact

The Auto Pact was signed in January 1965 and eliminated all tariffs to trade in cars, commercial vehicles, and auto parts. Prior to 1965, the car industry in Canada consisted mostly of U.S. manufacturers selling in Canada. The same manufacturers in the U.S. sold domestically. The effect of the Auto Pact was to profit from scale benefits in both countries. Factories in Canada would produce different models than factories in U.S., and sell in both markets.

Tariffs in Canada were of 17.5% for motor vehicles and auto parts before the agreement. In the United States, tariffs were of 8.5% for auto parts and 6.5% for motor vehicles, as described by Mason (1987) and Wonnacott (1987). These were eliminated in 1965.[2]

Figure 1 shows the ratio of bilateral trade to Canadian value added in the car industry. It was about 50% in 1961. By 1973, it had grown to almost 350%. This is exports from Canada to U.S. plus exports from U.S. to Canada in transportation equipment relative to value added in the transportation equipment sector in Canada. See Appendix B for sources of data. Figure 2 compares the evolution of trade in the car industry with all other bilateral trade. Both series are normalized to 1 in 1961. Clearly, there is no change in the trade series for non-auto trade, but huge changes in the auto trade series.

Next I turn to productivity in the automotive sector. The main problem is the lack of good, comparable data. I found no measures of sector value added per hour or per worker for this period in both countries. There is however data on output per worker in both countries, so I define this as

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[2] While some non-tariff barriers were introduced by the agreement, Fuss and Waverman (1986) conclude that they were mostly non-binding. For example, a car subject to no tariffs should contain at least 50% of Canadian or U.S. content. The actual content all through the period 1965-1980 was actually higher.

my measure of productivity. Statistics Canada provides data on output per hours worked in Canada since 1961 on the Transportation Equipment Manufacturing industry (NAICS code 336). The Bureau of Labor Statistics provides data on the Motor Vehicles and Equipment industry (SIC 371) for the U.S. since 1958.

Clearly, output per worker is a much worse measure of productivity than measures based on value added. Still, there are two main reasons why its use is justified in this case. First, I am comparing two very similar countries in terms of development and in a narrowly defined industry, so one can make the case that the structures of production are similar, and therefore movements in value added based measures should not be too different from movements in output based measures.

Second, under some technological assumptions, that are fairly common in the literature, the evolution of value added per worker is exactly the same as the evolution of revenue per worker. Consider the case of Cobb Douglas technologies. If the production function is $Y_t = A_t(K_t^{\alpha} L_t^{1-\alpha})^{\nu} M_t^{1-\nu}$, where A is a productivity parameter, K is capital, L is labor, M is intermediate goods, $\alpha \in (0,1)$ and $\nu \in (0,1)$, then output per worker is proportional to value added per worker, so that movements in one correspond to proportional movements in the other one. To see this, write down total revenue and value added are, respectively, $R_t = p_{yt} Y_t$, and $VA_t = R_t - p_{mt} M_t$, where p_m is the price of intermediate goods and p_y is the price of output. Cost minimization implies $p_{mt} M_t = (1-\nu) p_{yt} Y_t$, so that $VA_t = \nu R_t$. Dividing through by the number of workers shows the proportionality.

Figure 3 plots the productivity of the Canadian car industry divided by the productivity of the American car industry from 1961 to 1973.[3] Following the Auto Pact, the productivity of the Canadian car industry grew 22% more than the productivity of the American car industry from 1965 to 1973. This evidence suggests that the Auto Pact had the effect of increasing productivity in Canada more than in the U.S.

4. The Free Trade Agreement

The Free Trade Agreement between Canada and the United States came into effect on January 1989. The agreement specified a sequence of tariff and non-tariff barrier reductions that would completely eliminate trade barriers within the course of ten years. A group of goods eliminated tariffs immediately. A second group eliminated them gradually over five years (20% per year). A third group eliminated them gradually over ten years (10% per year). Trefler (2004) calculates bilateral tariffs for all manufacturing codes at the 4-digit level from 1980 to 1996. Figure 4 plots average tariffs in the U.S. and in Canada using his data.

Figure 5 shows trade volumes. The figure plots exports from Canada to U.S. plus exports from U.S. to Canada over Canadian manufacturing value added. See Appendix B for sources of data. Trade volumes grew by 80 percent during the Free Trade Agreement, and grew even further in subsequent years.

Next I turn to manufacturing productivity. Trefler (2004) finds that the tariff drops led to an

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[3] I stop in 1973 because after that the oil crisis contaminates the sample. While the U.S. was subject to international oil prices, Canada introduced oil export taxes and therefore was not subject to the high world prices. This affected output per worker differently in each country.

average increase in Canadian manufacturing productivity of between 5 and 8.3 percent. Rubini (2014) finds that the increase in U.S. productivity was almost negligible. Bernard and Jensen (1999) estimate that the productivity gains from trade in the U.S. are, if anything, very small. Thus, we should expect Canada's manufacturing productivity to have grown much more than U.S. manufacturing productivity. However, Van Ark et al. (2002) find this is not the case. This conclusion comes from studying the data collected by the GGDC 60 industry database. They find manufacturing value added per hour in Canada fell relative to the United States by 36 percent.

To explore this in greater detail, I turn to more disaggregate industry specific productivities. Figure 6 plots the evolution of productivity in Canada relative to the United States for each manufacturing industry in the GGDC 60 industry database.[4] In 17 out of 26 industries, Canadian productivity grew faster than U.S. productivity. These industries accounted for three fourths of manufacturing value added in each country. Thus, it must be the case that in some of the 9 industries in which the U.S. outgrew Canada, the differential rates of growth were spectacular enough to account for the fact that aggregate manufacturing productivity grew much more in U.S.

This is true for only two industries: Office machinery and Electronic Valves and Tubes. Office Machinery contains mainly computers, and Electronic Valves and Tubes semiconductors. In the United States, the productivity in Office Machinery grew by a factor of over 210 between 1988 and 1998. In Electronic Valves and Tubes U.S. productivity grew by a factor of 12. In Canada, the respective sector productivity growths are 11 and 2. Thus, U.S. productivity grew almost 20 times more in Office Machinery, and 6 times more in Electronic Valves and Tubes. Figure 7 shows the growth rates in the remaining industries. These are nowhere near the spectacular growth of Office Machinery or Electronic Valves and Tubes.

A well-known problem in comparing internationally the Office Machinery and Electronic Valves and Tubes industries lies in the price deflator. As Van Ark et al. (2003) argue, it is extremely hard for countries to account for the changes in the capabilities of computers and semiconductors, which have improved tremendously during the period of analysis. Only a few countries have an adequate system for measuring prices of computers and semiconductors. While the United States and Canada have their methods, these differ enormously, which makes statistics hard to compare.

To give an idea of how much these price deflators differ, consider their growth rates throughout the period. These price deflators are normalized to 100 in 1995. In the United States, the price deflator for Office Machinery in 1988 was equal to 1550, and it dropped to 16 by 1998. In Canada, the respective numbers are 962 and 120. Something similar happens in the Electronic Valves and Tubes sector. The price deflator in the U.S. in 1988 was 294, dropping to 51 by 1998. In Canada, the deflator increased slightly from 91 to 97.

In light of this problem, I use the same price deflators in both countries. Van Ark et al. (2003) use a common ICT price deflator to compare Canadian, U.S. and European industries. They use U.S. price deflators. The problem is that U.S. prices change so much that the change in the industries affected by these prices has an enormous impact on the aggregate. In fact, using U.S. price deflators for these two industries implies that the behavior in these two industries determines the

[4] Canada does not report anything for Other Instruments, so I exclude the industry.

behavior of the entire manufacturing industry, which seems unreasonably in light of these industries representing about 1.2% of manufacturing value added in Canada and less than 5% in U.S. (averages for all periods).

For this reason, I use Canadian price deflators to compute constant price value added for these industries in U.S., which implies these industries weigh in much less on the aggregate. Thus, I reconstruct the series of U.S. constant price value added using Canadian prices adjusted for relative manufacturing inflation[5] for these two industries. The details of how I do this are in the appendix. Figure 7 shows the change in the evolution of productivity in Office Machinery with and without the adjustment in U.S., and Figure 8 shows it for Electronic Valves and Tubes.

The results at the aggregate level using the adjusted series overturn the previous results. Figure 9 shows three series for Canadian manufacturing productivity relative to U.S. The first is unadjusted, and this is the same as Van Ark et. al. (2002). The second adjusts the price deflators in the two mentioned industries: Office Machinery (ISIC 19) and Electronic Valves and Tubes (ISIC 22). The third series excludes ISIC industries 19 and 22 from the analysis. First, one can see that unadjusted, Canada seems to lose about 36% of productivity relative to US in just 13 years. Focusing on the adjusted series, Canada actually gains relative to U.S. close to 13%. If we directly exclude Industries 19 and 22 from the analysis, the gain is even higher, of 17%.

The difference between these series illustrates the importance of the different price adjustments. Excluding the two industries covers more than 95% of manufacturing value added, since the industries represent less than 5 percent of manufacturing value added in U.S. and 1.2 percent in Canada, but greatly overturns the results from studying the unadjusted series. However, it only barely changes the results when studying the adjusted series.

This new evidence shows that manufacturing productivity grew faster in Canada than in U.S., as in the case of the Auto Pact; again suggesting that trade liberalization is associated with productivity increases. The productivity increase is larger where trade is more important.

5. Conclusion

I have explored the effects on productivity of two important trade liberalization episodes between the United States and Canada. The first is the Auto Pact in 1965. The second is the Free Trade Agreement that started in 1989. It has been widely understood that these pacts have had large effects on the volume of trade, but the effects on productivity are more puzzling. Regarding the Auto Pact, the reason for our narrow understanding is the lack of data. In this paper, I have constructed a dataset that can help us understand and compare the behavior of Auto productivity in these two countries. The analysis of this data concludes that following the Auto Pact, Canadian Auto productivity grew more than productivity in the United States.

In the case of the Free Trade Agreement, our lack of understanding stems from the different results that different databases yield. Trefler (2004) finds that the agreement increased productivity in Canada. Van Ark et al. (2002) find that aggregate manufacturing productivity in the United States grew more than in Canada.

[5] The results are very similar when using aggregate inflation.

I find the conclusion in Van Ark et al. (2002) is driven by the use of price deflators that are not comparable in the computers and semiconductors industries. When using comparable price deflators for both countries, I find that Canadian productivity actually grew more than U.S. productivity, consistent with Trefler (2004).

The evidence collected suggests that trade liberalization produces productivity gains. This is puzzling in light of current trade models as Melitz (2003) or Eaton and Kortum (2002), where aggregate productivity is independent of trade costs. However, some extensions of these models are suitable for generating gains in measured productivity from reductions in trade costs. Rubini (2014) shows that introducing innovation to a Melitz (2003) model as in Atkeson and Burstein (2010) can generate increases in measured productivity. Models with variable mark-ups would have the same effect. We need to concentrate on these types of model to understand the effects of trade liberalization on economic outcomes.

The fact that trade liberalization increases productivity has important policy implications. In particular, some studies argue that trade liberalization is associated with job losses in the short term (see Trefler, 2004, Kambourov, 2009, and Pierce and Schott, 2014). The fact that productivity increases provides welfare gains that counteract the welfare losses associated to a lower level of employment. Moreover, if these productivity increases persist, industries where productivity increased will export more, absorbing more employees, and possibly counteracting the initial losses in jobs.

In any case, the fact that there are increases in productivity is a strong argument in favor of trade liberalization. In particular, it can help us understand better the cases of China and South Korea, to name a few, where huge productivity gains came alongside trade openness. The literature should start using models that deliver productivity gains to study these events.

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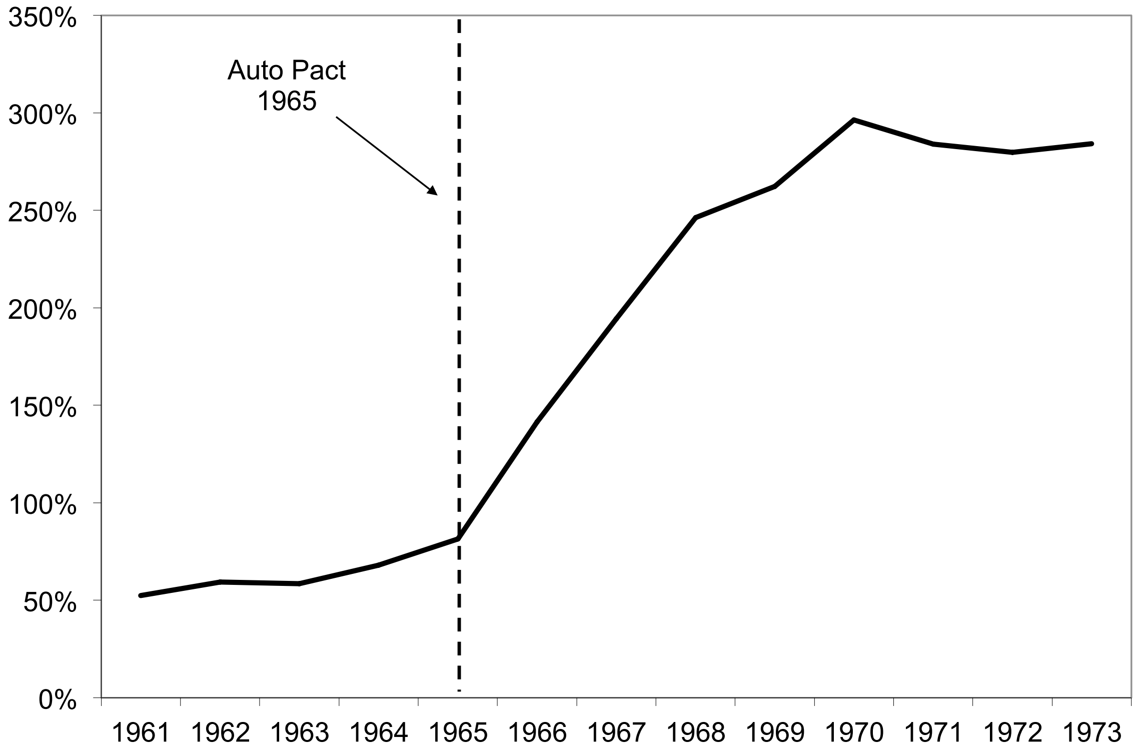
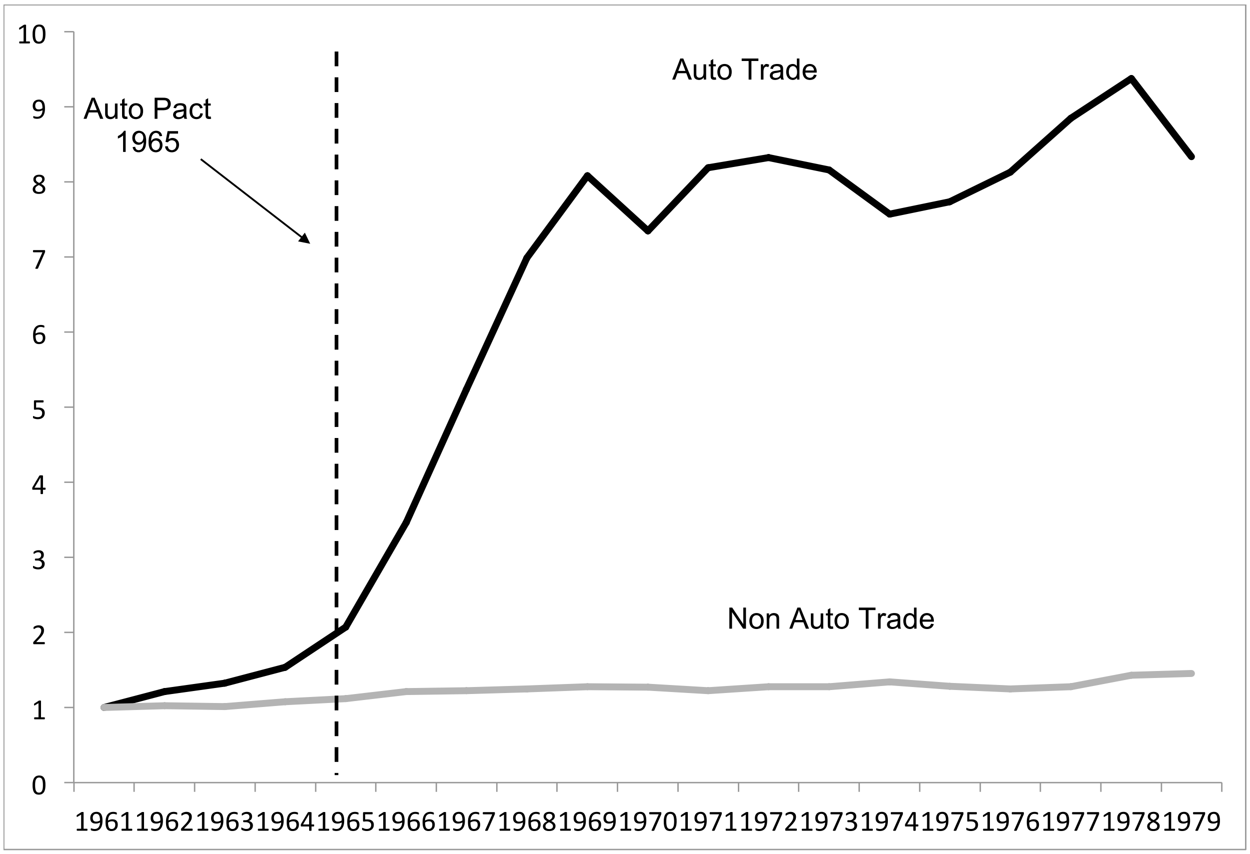
APPENDIX A: Figures

Figure 1: Automotive Bilateral Trade Relative to Canadian Auto Value Added



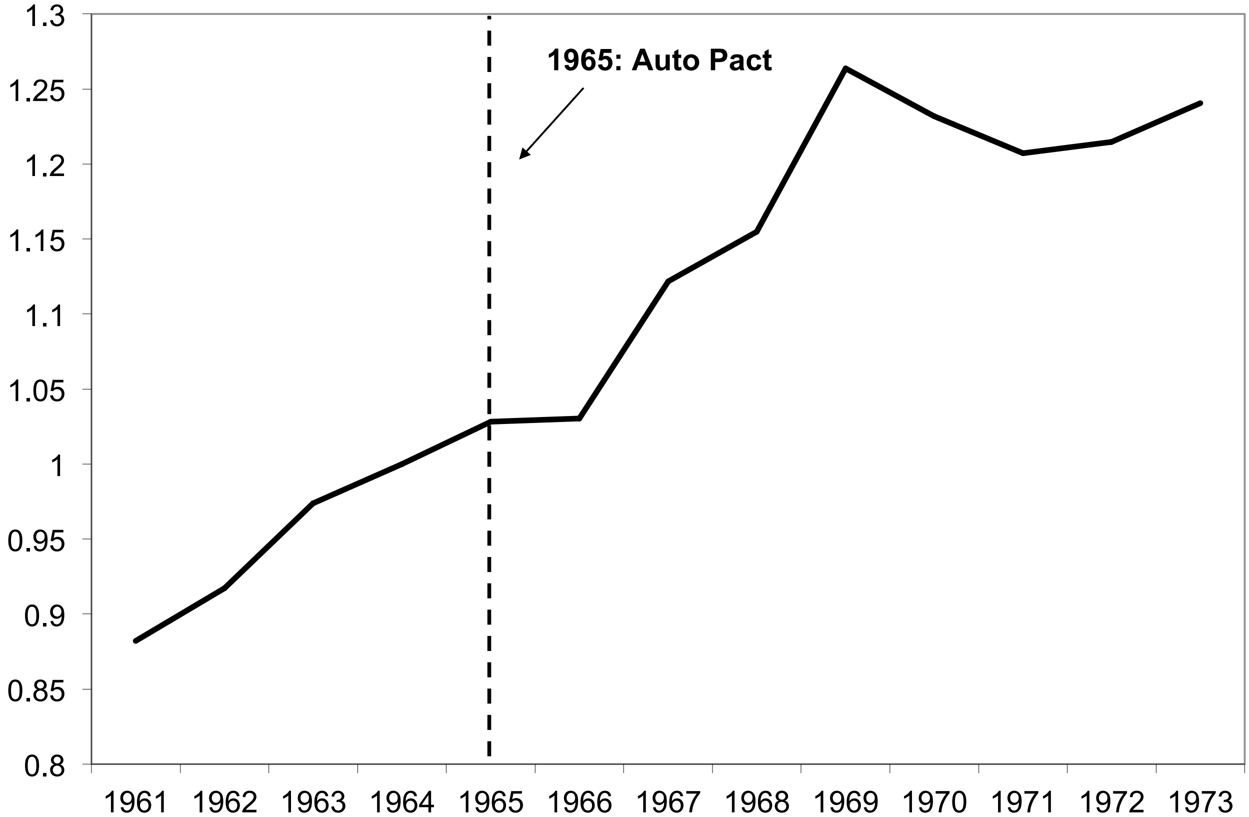
Note: Bilateral trade includes exports from Canada to U.S. and from U.S. to Canada.
Source: OECD, Statistics Canada and World Development Indicators.

Figure 2: Auto vs. Non Auto Trade



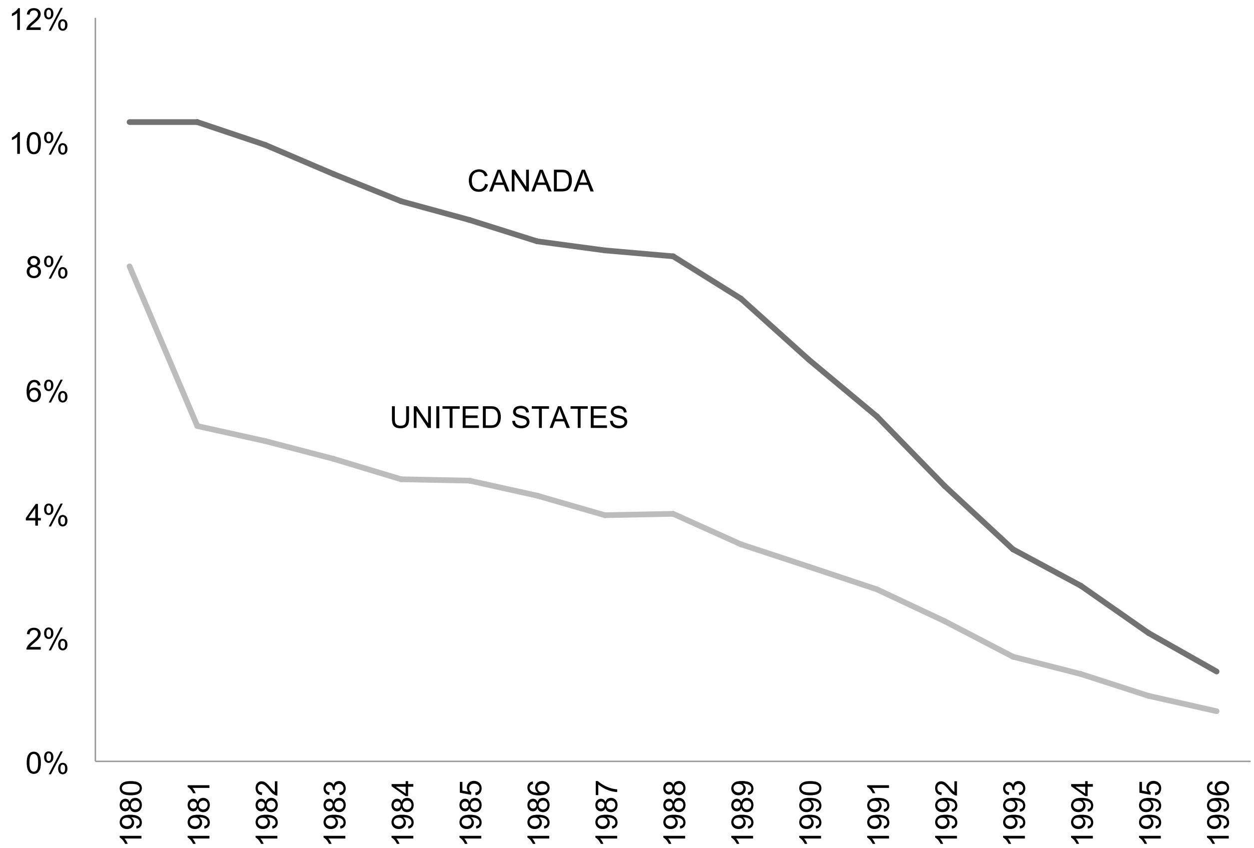
Note: Figure plots the sum of exports from Canada to U.S. and from U.S. to Canada. The black line includes the automotive trade, while the grey line includes all other trade. The series are normalized to equal 1 in 1961.
Source: OECD and Statistics Canada.

Figure 3: Automotive Productivity in Canada Relative to U.S.



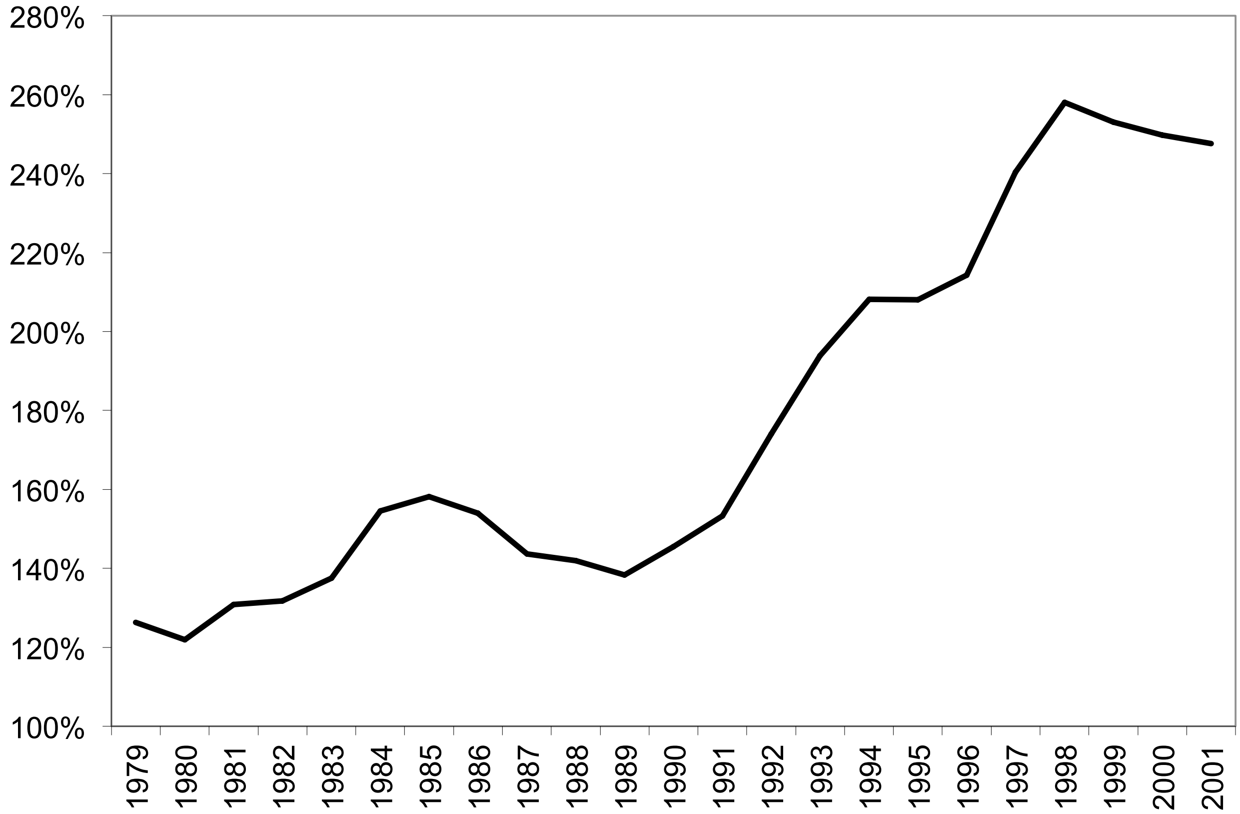
Note: Productivity is revenue divided by number of workers. The figure plots this ratio for Canada divided by the ratio for the U.S. The series is normalized to equal 1 in 1964. Source: Statistics Canada and Bureau of Labor Statistics.

Figure 4: Average Tariffs in Canada and U.S. for bilateral trade



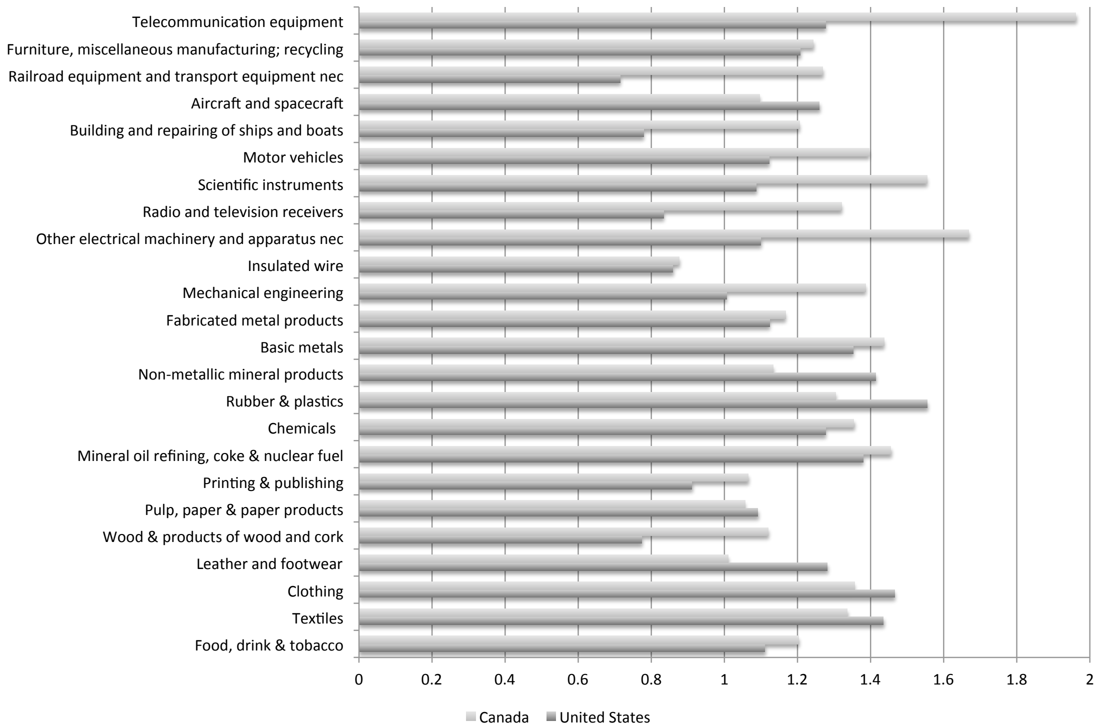
Source: Trefler (2004).

Figure 5: Bilateral Trade Relative to Value Added



Note: Figure shows the ratio of the sum of exports from Canada to U.S. plus exports from U.S. to Canada relative to Canadian manufacturing value added. The shaded area represents the years in which the Free Trade Agreement was in practice. Source: GGDC 60 Industry Database, World Development Indicators and OECD.

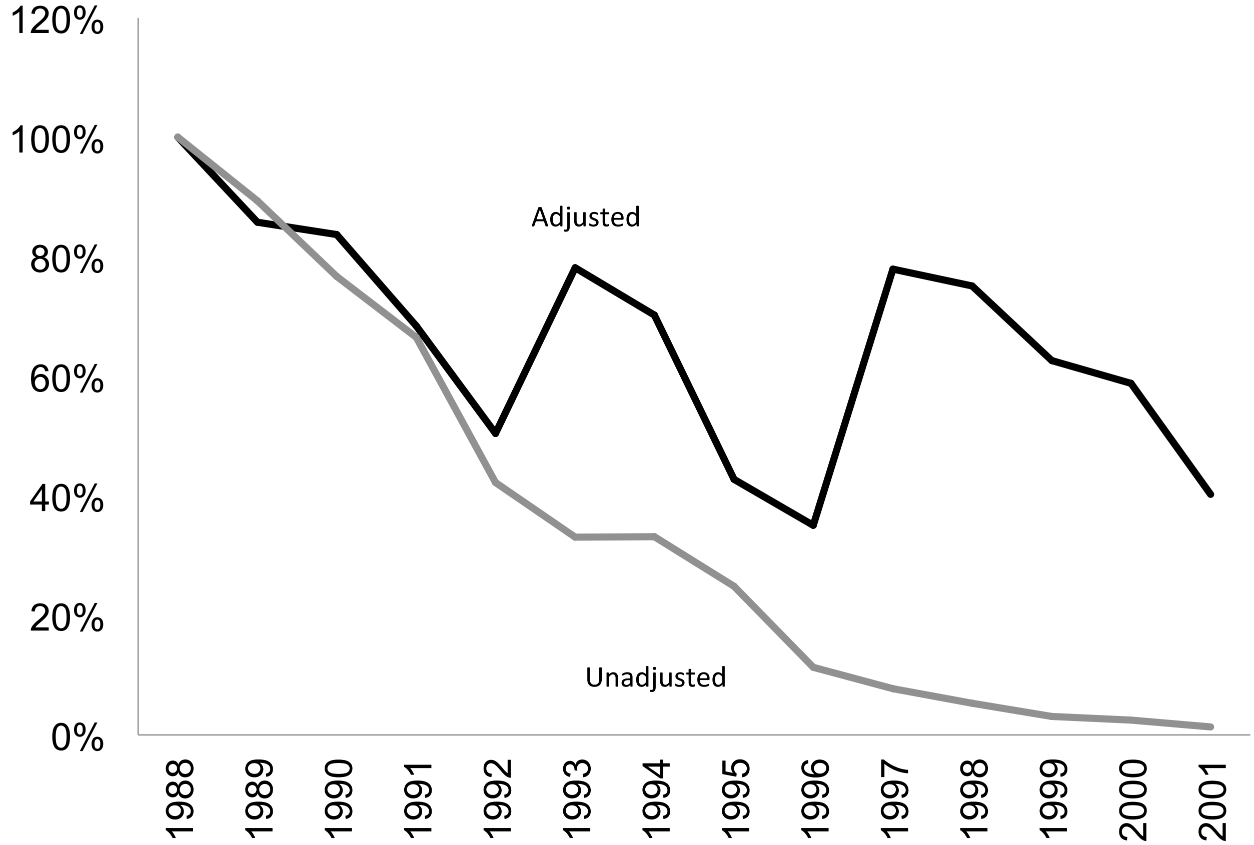
Figure 6: Growth in Productivity per Industry



Note: the bars show the growth in productivity per industry for Canada and U.S., using all the manufacturing industries in the GGDC 60 industry database, except for Office Machinery and Electronic Valves and Tubes.

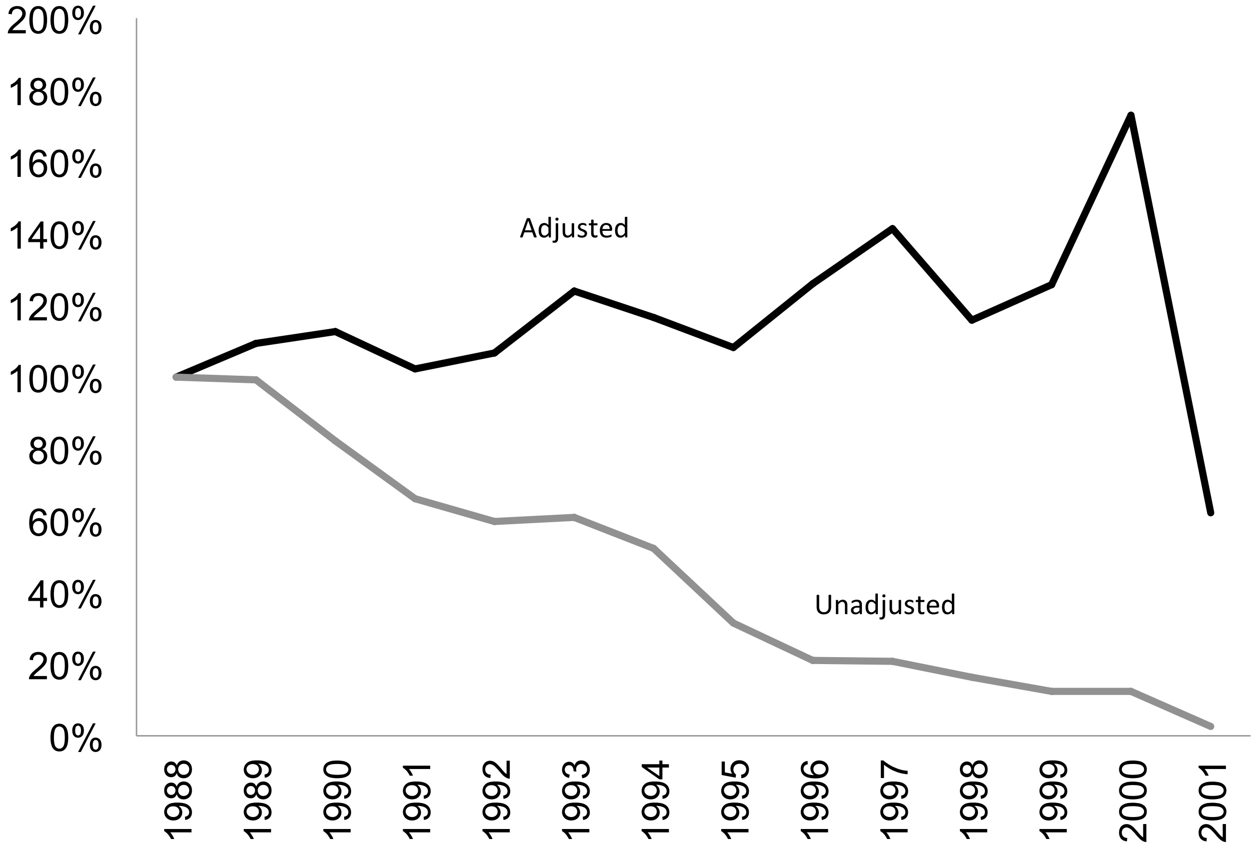
Source: GGDC 60 Industry Database.

Figure 7: Adjusted and Unadjusted Relative Productivity in Office Machinery



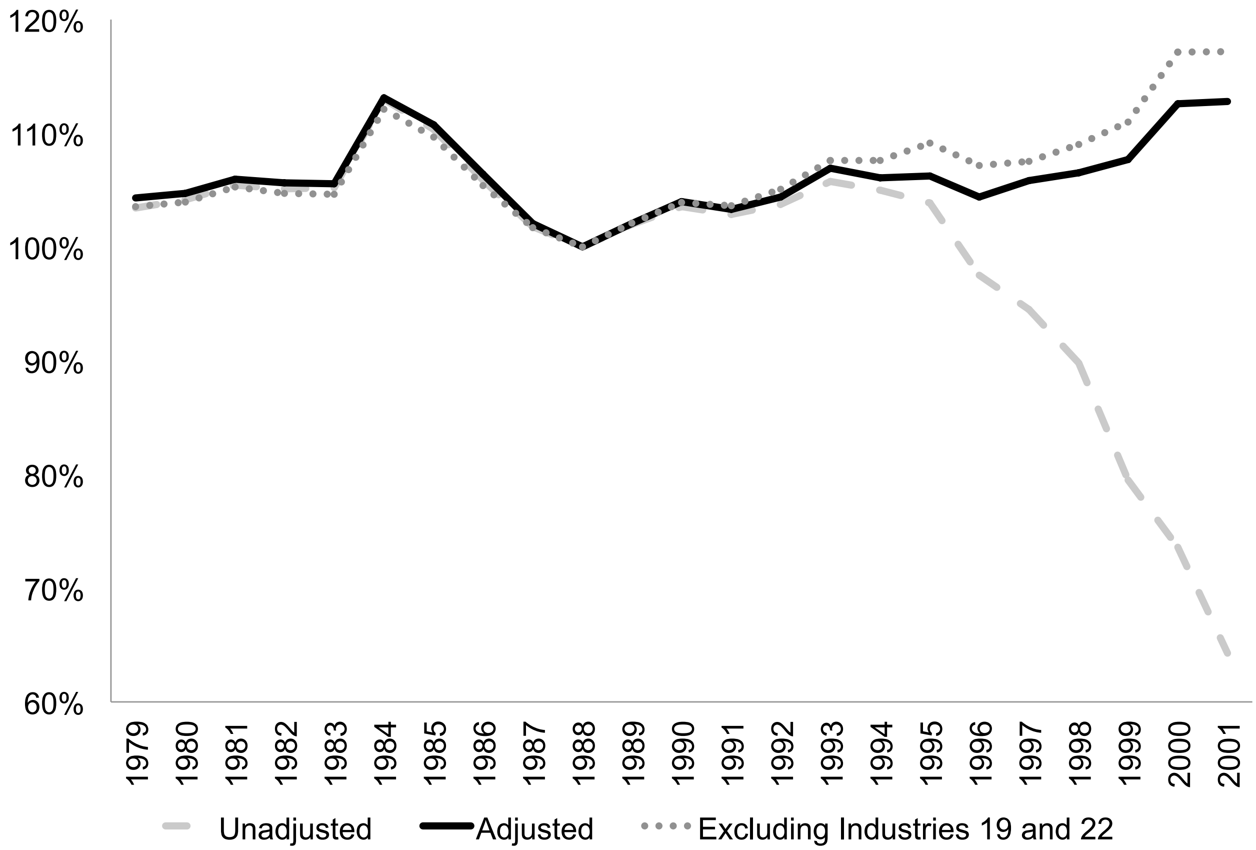
Note: The lines show the productivity in the Office Machinery industry, Canada relative to U.S. The grey line shows the data from the GGDC 60 Industry database. The black line uses Canadian price deflators (adjusted by the difference in inflation rates) to compute U.S.
Source: Author's calculations based on GGDC 60 Industry Database.

Figure 8: Adjusted and Unadjusted Relative Productivity in Electronic Valves and Tubes



Note: The lines show the productivity in the Electronic Valves and Tubes industry, Canada relative to U.S. The grey line shows the data from the GGDC 60 Industry database. The black line uses Canadian price deflators (adjusted by the difference in inflation rates) to compute U.S. Source: Author's calculations based on GGDC 60 Industry Database.

Figure 9: Productivity in Canada relative to Adjusted Productivity in U.S.



Note: Figure plots the aggregate manufacturing productivity in Canada relative to U.S. under three different measures. The first uses unadjusted data from the GGDC 60 industry database. The second adjusts the price deflators for the Office Machinery (ISIC 19) and Electronic Valves and Tubes (ISIC 22) in U.S. by using the Canadian price deflators. The third excludes Office Machinery and Electronic Valves and Tubes from the Analysis. Source: Author's calculations based on GGDC 60 industry database.

APPENDIX B: Data Sources

Auto Pact

- Tariffs: Wonnacott (1987)
- Output per hour worked in constant prices Canada in the Transportation Equipment Manufacturing Industry (NAICS code 336) from Statistics Canada.
- Output per hour worked in constant prices US in the Motor Vehicles and Equipment Industry (SIC 371) from the Bureau of Economic Analysis.
- Trade: Organization for Economic Cooperation and Development (OECD).
- Real exchange rate Canada-US: World Development Indicators.

Free Trade Agreement

- Tariffs: Trefler (2004)
- Value added per hour worked in constant prices: Groningen Growth and Development Centre (GGDC) 60 industry Database.
- Trade: Organization for Economic Cooperation and Development (OECD).
- Real exchange rate Canada-US: World Development Indicators.

APPENDIX C: Adjustments to Office Machinery and Electronic Valves and Tubes

The 60-industry database of the Groningen Growth and Development Centre (henceforth "GGDC") provides detailed data on current price value added, hours worked and value added in volume indices (1995=100) for 60 industries. I focus on manufacturing industries. Following the GGDC, these are industries 5 to 31. To obtain aggregate manufacturing productivity in constant prices I multiply the value added in volume indices by the 1995 current price value added. I add these numbers for industries 5 to 31 and then divide the resulting number by the sum of hours worked in these industries.

I use the Canadian price deflator to calculate real productivity in the Office Machinery and Electronic Valves and Tubes in the U.S., adjusted for U.S. inflation. To perform the inflation adjustment I proceed as follows. The GGDC computes industry value added in volume quantities, with 1995=100. Let VAK_{it} be the index of constant price value added, VA_{it} is current price value added, and Def_{it} is the deflator, all at time *t* and industry *i*. The formula for the constant price index is

$$VAK_{it} = \frac{VA_{it}/Def_{it}}{VA_{i95}/Def_{i95}}$$

The normalization is $Def_{i95} = 100$. To calculate Def_{it}, the GGDC obtains price rates of growth from individual country sources. Let the rate of growth be g_{it}. Then

$$Def_{it} = \frac{Def_{it+1}}{\exp\left(g_{it+1}\right)}$$

The increase in price deflator can be split into two components: aggregate manufacturing price change (inflation in the manufacturing sector) and industry specific price change. Given that the rates are exponential, $g_{it} = \pi_t + d_{it}$ where π_t is manufacturing inflation at date *t* and d_{it} is the difference between the rate of growth of an industry price over the rate of growth of general prices.

The first step is to calculate manufacturing inflation excluding office machinery and electronic valves and tubes. To do this I follow the same methodology as the GGDC uses to calculate inflation, with the exception of the industries under concern. The GGDC provides the exponential growth rates for every industry. Inflation is calculated as:

$$\pi_t = \frac{\frac{\sum_i g_{it} VA_{it}}{\sum_i VA_{it}} + \frac{\sum_i g_{it+1} VA_{it+1}}{\sum_i VA_{it+1}}}{2}$$

where the subscript *i* includes manufacturing industries. This gives the manufacturing inflation rates in Canada and U.S. Next I subtract the Canadian manufacturing inflation rate from the rate of growth of the prices in these sectors in Canada. I add to these numbers the manufacturing inflation rate in U.S. The resulting number is the rate of growth of sector prices in U.S.