TRADE BETWEEN ADVANCED AND UNDERDEVELOPED COUNTRIES A PASINETTI MODEL MEXICO-US 2013-2018 §

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Abstract

In this work, we construct an empirical model based on Pasinetti's writings to analyze trade between an advanced country, the United States, and an underdeveloped country, Mexico. This model utilizes actual data from the US and Mexico. Our findings show that Pasinetti's trade theories regarding advanced and underdeveloped countries fully apply to the US-Mexico case during the period 2013-2018. Consequently, his theses about this type of trade are confirmed: Mexico's terms of trade with the US worsen; there are not gains from trade in terms of productivity for Mexico, but leakages of productivity gains from Mexico to the US.

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I. Introduction

In his *Structural Change and Economic Growth* (1981), Luigi Pasinetti developed a model for economic growth analyzing the most critical issues involved in the discussion including International economic relations. For developing his ideas on international trade within the context of his growth model, Pasinetti analyzes trade between an advanced country and an underdeveloped one, relating the improvement or worsening of the terms of trade between them to the goods each produces and exports. In the last instance –he argues– it depends on "comparative international changes in *productivity*." On this topic he refers to Raúl Prebisch (1959) as a pioneer.

Pasinetti's general principle that rules international trade called *comparative productivity-change advantage* is said to derive from Ricardo's principle of "comparative cost advantage," but from a quite distinct perspective than the accepted Neoclassical interpretation in the Heckscher-Ohlin model. The core of Pasinetti's argument is that:

> what a country obtains from abroad through international trade is a certain collection of *physical commodities*, in exchange for a physical labor embodied in the physical collection of commodities that are exported. Hence the normal and primary way of obtaining increases in the physical collection of imported goods is through a diminution of the quantity of labor embodied in each physical unit of exported goods...There is, however, also another way which consists in a change (an increase) of the physical amounts of goods which are imported per given physical amounts of goods which are exported, i.e., an improvement in of what has been called the 'terms of trade', or ratio of the (weighted) average prices of exports to the (weighted) average prices of imports (Pasinetti 1981).

This way, he argues, a country will be able to get benefits (productivity gains) through international trade from the rest of the world. Then he raises two important questions: what are the dynamics of the terms of trade? And what is the relation of these dynamics to the economic growth of the countries concerned?

To answer these questions the rest of his theoretical analysis involves the dynamics of three main variables for each trading country: Prices, Productivity and Wages, These variables are not evaluated in macroeconomic terms, but in meso-economic ones, that is, under an inter-industry approach like his model. What is relevant for the "Center-Periphery" debate is the resulting analysis of the possible outcomes for the interaction of these variables between advanced and underdeveloped countries, which might show a sort of "unequal exchange" between them.

In this work we build an empirical model based on Pasinetti's writings and models to apply Pasinetti's analysis of trade between an Advanced country -the United States- and an Underdeveloped country -Mexico. This modelling is based on actual data from the US and Mexico's official agencies.

The paper is divided into six sections including this introduction. In the second section we review the relevant literature regarding this topic. Starting precisely with Prebisch' original thesis and his supporters and critics. In the third, we specify the purpose of this analysis and the hypothesis, the scope, and the methodology. In the fourth section we present the applied models. In the fifth section we analyze the results of the applied models. The closing section is for conclusions.

2.1 Prebisch, Unequal Exchange, and the Terms of Trade

Raúl Prebisch (1959) was the first of the non-Marxist authors to propose the concept of unequal exchange between developed and underdeveloped countries. This inequality leads to a situation in which underdeveloped countries face chronic foreign trade deficits or low product growth rates. Structuralists like Hirschman (1957) emphasized this phenomenon, known as the *external gap* in development economics.

Prebisch (1959) begins by arguing that the spread of technical progress was uneven, contributing to the division of the world economy into industrial centers and peripheral countries, the former producing and exporting manufactures, the latter primary goods. As technical progress spreads into the periphery, it necessitates industrialization. Nevertheless, the industrialization of the periphery was a contentious topic. Some viewed it as a detrimental diversion of productive resources from primary activities, according to Neoclassical thinking. Their argument, as Prebisch states, was: "Let the peripheral countries increase productivity in their primary activities through much-needed technical progress and thus expand their exports. Their rate of development will then be accelerated on a sound basis" (Prebisch, 1959).

However, this is not happening. According to Prebisch, the growth rate in underdeveloped countries is limited by the low-income elasticity of demand for primary goods in developed countries, as opposed to the high-income elasticity of demand for manufactured goods exported by developed countries. Consequently, disparities in income elasticities of demand and development persist in foreign trade as well. These disparities create pressure on export prices, leading to a deterioration in the terms of trade due to the unrestricted play of market forces. To address a foreign trade deficit and declining terms of trade, the Neoclassical solution would be currency depreciation. In this scenario, wage levels measured in foreign currency must drop to reduce industrial costs to a level competitive with imports, both expressed in foreign currency.

But the cost of so-called spontaneous industrialization through exchange depreciation involves transferring abroad part of the real income increment derived from employing what Prebisch calls surplus manpower—redundant labor resulting from technical change. This income increment represented the fruits of increased productivity. Therefore, the periphery transfers part of these fruits to employ surplus manpower whenever exports must increase.

In summary, for Prebisch, unequal exchange means a transfer of real income, which is the result of increased productivity from an underdeveloped country to a developed one through trade between them, under conditions of declining terms of trade for the underdeveloped country and subject to exchange rate depreciation to correct the deficit as a means of industrialization under free trade. This argument has always been used to recommend protectionist policies for industrialization in Latin America. Hans Singer (1950), also a structuralist, presented similar ideas to Prebisch, thus the proposition eventually became known as the "Prebisch-Singer thesis."

An excellent history of the thesis and Prebisch himself is presented in Love (1980). This work shows that during the 1960s and 1970s, many Latin American economists endorsed Prebisch's policy recommendations for industrialization and development. Yet, Octavio Rodríguez (2001) is undoubtedly the most significant and persevering of Prebisch's followers.

From Prebisch's original work in the late 1950s to the end of the last century, there was a debate between orthodox economists and structuralists (Prebisch's followers) empirical validity of the declining tendency of the terms of trade between underdeveloped and developed countries. This decline was established by Prebisch as the cause of low growth or increasing trade deficits in the former, justifying the need for protectionist policies to encourage industrialization and growth.

The renowned author Charles Kindleberger in his textbook (1973) addresses the questions raised by Prebisch regarding commercial policy, mixing them with ideas from other authors and interpreting the possibility of unequal exchange (which he terms unequal bargaining) as depending on the secular declining tendency of the terms of trade between underdeveloped and developed countries. Subsequently, the work of Grilli and Yang (1988) became the most renowned against the Prebisch-Singer thesis but yielded ambivalent results. On the other side of the debate, Sarkar, and Singer (1991) and Sapsford, Sarkar, and Singer (1992) offered counterarguments to Grilli and Yang in favor of the Prebisch-Singer thesis. Finally, Maizels (2000) conducted a statistical analysis on the same topic, concluding that the terms of trade tendencies between underdeveloped and developed countries in the latter part of the past century confirm the Prebisch-Singer thesis.

2.2 Pasinetti's Theory of International Trade with Technical Progress

The issue of international economic relations is addressed in Pasinetti's book *Structural Change* (1981). He also discusses the problem of international trade and technical progress in a later article (Pasinetti, 1988). In both writings, Pasinetti strongly rejects the Neoclassical theory of comparative costs developed in the Heckscher-Ohlin model (H-O) and extended by Paul Samuelson (H-O-S). He claims there are two main predictions derived from the H-O-S model which are contradicted by reality. One is that what he calls "received theory" predicts specialization in sectors operating at constant returns to scale (manufactures) and non-specialization in those sectors operating at decreasing returns to scale (agriculture and mining), while in the real world the opposite is true. The other prediction is that under conditions of free trade, there will be an equalization of factor prices between trading countries. However, in the real world, “the equalization of the wage rate and the rate of profit is never observed, not even as a tendency” (Pasinetti 1988). A third element of criticism of the H-O model is the “Leontief Paradox.” The results of the Heckscher-Ohlin theorem test in the U.S. economy show that the U.S. (the most well capital-endowed in the world) is exporting labor-intensive goods and importing capital-intensive goods (Leontief, 1953) in clear opposition to what the H-O theorem predicts. Pasinetti criticized in his writings all economic growth theories that neglected technological change, which comes from technological knowledge, as a main source for economic growth. It is not surprising that with respect to international trade theory, he argues that “the single most serious shortcoming of the theory is its failure to deal with changes in technical knowledge” (Pasinetti 1988). Among classical economists, Ricardo (1821 [1973]) emphasized the role of costs in international trade and thus technology but underestimated the effects of technical progress, according to Pasinetti.

As the essential part of his international relations theory, Pasinetti postulates that “what accounts for the disparities in wealth and in the behavior of different countries is not so much the difference in factor endowments [as Ohlin argues] as the differences in technical knowledge” (Pasinetti 1988).

Pasinetti presents his own theory of international relations, precisely debating the Neoclassical view of the H-O as a mutual gain situation (see, for instance, Markusen et al. 1995). In his model, he assumes the opening of economic relations between two different countries: one advanced (A) and the other underdeveloped (U). The difference between them is that productivity per worker is ten times higher in country A than in country U for each single consumption good. Thus, while prices are, of course, different in absolute terms between the two countries, the structure of relative prices is assumed to be the same. Pasinetti is working on a multi-sectoral model.

In this situation, the only possible gain that one country could obtain in its economic relation with the other is *technical knowledge*. While from the point of view of country A there is nothing it can learn from country U, the case of country U is quite different. By opening up relations with country A, its inhabitants may learn the production methods already in use in A, which means that the U economy can grow as fast or even faster than the A economy (Pasinetti, 1981). However, it all depends on the structure of demand, which is of course different in country U than in country A. It also depends on the possible rates of expansion of the sectors whose production weighs more in that structure. This means these sectors are the first in which new production techniques must be learned and applied. Therefore, there must be an *order* in the process of learning and applying new production techniques for country U.

When Pasinetti removes from his model the assumption that both countries have the same structure of relative prices, trade then appears as a secondary source of international gains. If relative costs within each country may determine relative advantages between countries A and U, then the question is what determines relative cost differences. There are various causes, including different natural resource endowments, different climates, and especially the various stages of economic development in which each of them may be. All of these factors cause different productivity levels between the two trading countries. In this case, the assumption of an overall average productivity of ten to one (country A versus country B) must be modified to account for different sectors' productivity between the two countries, with a wide range of variation.

In this situation, the question for Pasinetti becomes: “Should international [free] trade be allowed? Are movements of commodities across borders beneficial to the two countries?” It depends on two conditions that must be satisfied, Pasinetti argues. These are: (1) At the time that exchange takes place initially, the structure of costs in each country should be the best possible one; (2) Each country must be able to specialize in specific sectors, moving labor and capital from one sector to another, without losing full employment or increasing unemployment. The first condition implies that if an advanced production technique for a particular commodity can be learned in a brief time from abroad, so as to reduce its local price to the international level, it is more advantageous to produce it at home than to import it.

If these conditions are fulfilled and specialization in each country takes place, both countries will produce and/or trade more physical quantities of all commodities than before trade, resulting in mutual gains. According to Pasinetti, this would be the result of Ricardo's principle of comparative cost advantages (Pasinetti 1981).

Once trade starts between these two countries, there will be various effects on both economies, depending on factors such as the number of commodities that can actually be traded, the capacity of firms to either adapt to new competitors from abroad or expand for new demands and achieve increasing returns to scale, among others. But “the most important effect of this process of opening is on real incomes” (Pasinetti 1981). The lower prices obtained from imported goods and improvements in the production of local (tradable) commodities brought about by foreign competition will be reflected in real per capita income and demand increments in one or both countries. The relative prices of tradable goods in both countries become the same, but absolute and relative prices of non-tradable goods remain different in each country as before trade.

Once trade is established, the gains brought about by it cease, meaning they are realized once and for all. The only way they can be increased is through new international trade. Continuing the same international trade would result in no additional gains; while stopping it would result in a loss.

Any productivity improvement in a given country is created internally and translates into higher internal per capita incomes; it cannot spread abroad through trade. However, the increase in demand may benefit both countries.

2.3 The Terms of Trade

Next, in Pasinetti's analysis of trade is the consideration of the terms of trade and their changes over time. The terms of trade refer to the ratio of the weighted average prices of exports to the weighted average prices of imports. They describe the physical amounts of goods imported per given physical amount of goods exported. The changes in this ratio over time are due to technical changes affecting productivity in each country, as well as the terms of trade. In other words, productivity changes over time determine price changes. The country that improves its terms of trade through relative productivity increments may gain benefits from the countries it is trading in, and the reverse is also true. If its terms of trade worsen over time due to slower productivity changes compared to its trading partners, it would mean losing benefits to other countries.

In his growth model and price model, Pasinetti is clear in associating local prices with the labor embodied in any given commodity. In turn, the amount of labor per unit of output is the measure of productivity he uses throughout his analysis. He also associates wages with productivity. However, since wages are not equalized between countries engaged in trade and are, in fact, widely different between advanced and underdeveloped countries, the value of each commodity cannot be equal between countries since trade is about quantities. For example, a ton of iron is produced with different amounts of labor embodied, but it is still worth one ton of iron in trade.

Now, these productivity changes must be measured as an average in the production sector in which each country specializes for exports ϱ relative to the general average rates of productivity in that country R. Thus, we have two ratios to compare: one for the advanced country A ϱ_A/R_A and the other for the underdeveloped country U ϱ_U/R_U.

Through this comparison, whether one ratio is higher, equal to, or lower than the other, Pasinetti establishes the principle that the dynamics of the terms of trade depend on the comparative rates of change in productivity in the two countries. "It depends on comparative rates of change of productivity in the two countries" (Pasinetti 1981).

3. Hypothesis, Scope, and Methodology

We adopt Pasinetti's model to create applied models for the US and Mexico. With these models, we estimate key factors relevant to Pasinetti's critical view of trade relations between advanced and underdeveloped countries, in comparison to Prebisch's thesis of unequal exchange. The crucial variables for Pasinetti are the Terms of Trade variations, similar to Prebisch, and the ratios of productivity growth rates of exporting industries to common trading industries in each country. This is a particular argument of Pasinetti's growth model.

Pasinetti contends that the prices of exports from Mexico (an underdeveloped country) relative to the prices of imports from the US (an advanced country) – i.e., the terms of trade for Mexico – will improve, worsen, or remain unchanged over time based on whether:

(i) $\varrho_{e.p.}^{us} / R_p^{us} > \varrho_{e.p.}^{mx} / R_p^{mx}$ or

(ii) $\varrho_{e.p}^{us}$ / $R_p^{us} <$ $\varrho_{e.p.}^{mx}$ / R_p^{mx} or

(iii) $\varrho_{e.p}^{us}$ / $R_p^{us} = \varrho_{e.p.}^{mx}$ / R_p^{mx}

where $\varrho_{e.p}^{us}$ = weighted average growth rate of productivity in industries exporting to Mexico from the US in period p. R_p^{us} = weighted average growth rate of productivity in common trading industries in period p; $\varrho_{e.p}^{mx}$ = weighted average growth rate of productivity in industries exporting to the US from Mexico, in period p; R_p^{mx} = weighted average growth rate of productivity in common trading industries in Mexico in period p.

These alternative scenarios imply that over time, international trade may cause: (i) productivity gains to leak from the US to Mexico; (ii) productivity gains to leak from Mexico to the US; (iii) productivity gains to remain in the country where they originated (Pasinetti 1981).

To adapt Pasinetti's theoretical model to the actual economies of Mexico and the US, some assumptions used by Pasinetti for theoretical exposition needed modification for actual economic structures. First, there is no uniform rate of profit nor a uniform wage rate in each economy; these vary from industry to industry. Actual data on profit rates and wage rates were taken from official agency reports in both countries. Second, the model assumes free trade between these two countries, but within the context of the North American Free Trade Agreement (originally NAFTA and now USMCA), free capital flows are allowed, but not labor movements. The exchange rate, which Pasinetti assumes is constant over time, played no role in his model. However, in the period analyzed, the exchange rate of the Mexican Peso to the US Dollar varied significantly and may have influenced some of the variables in our study, so we also analyze this.

The hypothesis to be evaluated involves estimating these crucial variables through two models, one applied to Mexico and the other to the US, connected through trade relations, based on actual data for the period 2013-2018. The methodology is, of course, Input-Output analysis as used by Pasinetti in various works (Pasinetti 1975, 1977, 1981). The period of study is the years 2013 and 2018, for which the most recent Input-Output data for both countries are available from official sources. The classification system of industries known as the North American Industrial Classification System (NAICS) is the same for both countries, allowing direct comparison of data industry by industry. Economic variables are all measured in current US dollars, and labor is measured in terms of the number of workers. However, gross outputs for productivity estimation are measured in constant (2013) Mexican Pesos for Mexico and in constant (2013) US Dollars for the US. All variable values were obtained from the National Income Accounts of each country, as estimated by official agencies.

Using NAICS, we defined a set of 59 industries for each matrix of Mexico and the US. From this set, we selected 23 industries of traded goods between Mexico and the US to estimate the main variables of Pasinetti's analysis of international trade between the two countries. This subset includes all primary goods and manufactured products traded between the two countries, excluding services.

Pasinetti's model of production and its corresponding price system are detailed in Appendix I. The sources of statistical data and web references are listed in Appendix II.

4. Pasinetti's Input-Output models for Mexico and the US

4.1 Applied model to Mexico's economy

Based on Pasinetti's model (see Appendix I) we define for Mexico the following equations, maintaining the same notation, where the subscript/superscript ***mx*** stands for Mexico.

Besides the name of the variables, we specify the units in which each one is measured. The basic equations are essentially equal to those in the theoretical model.

$$\mathbf{x}^{mx.t} = \left(\mathbf{I} - \mathbf{A^{\theta}}_{mx,t}\right)^{-1}\mathbf{y}^{mx.t} \tag{1.1}$$

where: $\mathbf{x}^{mx.t}$ = annual gross output in current US dollars, in time *t*; $\mathbf{y}^{mx.t} =$ final demand in current US dollars in time *t*; $\mathbf{A^{\theta}}_{mx,t}$ = circulating and fixed capital matrices in time *t*; *t* = 2013 and 2018.

$$\mathbf{A^{\theta}}_{mx,t} = \mathbf{A}_{mx,t} + \mathbf{A^{F}}_{mx,t} \cdot \hat{\boldsymbol{\delta}}_{mx,t} \tag{1.2}$$

where: $\mathbf{A}_{mx,t}$ = input-output matrix in time t, $\mathbf{A^{F}}_{mx,t}$ = coefficient matrix of fixed capital in time t, $\hat{\boldsymbol{\delta}}_{mx,t}$ = diagonal matrix of depreciation rates in time *t*; *t* = 2013 and 2018.

$$\boldsymbol{\delta}_{mx.t} = (\delta_1^{mx.t}, \dots, \delta_i^{mx.t}, \dots, \delta_{59}^{mx.t})$$

$$\delta_i^{mx.t} = d_i^{\ mx,t}/K_i^{\ mx,t} \tag{1.3}$$

where: $\boldsymbol{\delta}^{mx.t} =$ depreciation rates vector in time *t*; $d_i^{\ mx,t}$ = depreciation by industry in current US dollars, in time *t*; $K_i^{\ mx,t}$ = productive capital by industry in current US dollars, in time *t*; *i* = (1, ... , 54), *t* = 2013 and 2018.

$$\mathbf{H}^{mx.t} = \mathbf{A}_{mx,t}\left(\mathbf{I} - \mathbf{A^{\theta}}_{mx,t}\right)^{-1} \tag{1.4}$$

where $\mathbf{H}^{mx.t}$ = vertically integrated capital goods coefficient matrix in time *t*; *t* = 2013 and 2018.

$$\mathbf{v}'^{mx.t} = \mathbf{a}'^{\ mx.t}\left(\mathbf{I} - \mathbf{A^{\theta}}_{mx,t}\right)^{-1} \tag{1.5}$$

where: $\mathbf{v}'^{\ mx.t}$ = vertically integrated labor per unit of output vector in time *t* and $\mathbf{a}'^{\ mx.t}$ = labor coefficients vector in time *t*; *t* = 2013 and 2018.

$$\mathbf{a}^{mx.t} = (\mathrm{a}_1^{mx.t}, \dots \mathrm{a}_j^{mx.t} \dots \mathrm{a}_{59}^{mx.t})$$

$a_j^{mx.t} = l_j^{mx,t} / x_j^{mx,t}$ (1.6)

where: $l_j^{mx,t}$ = labor units by industry *j* in time *t* and $x_j^{mx,t}$ = gross output in current US dollars by industry *j* in time *t*; *j* = (1...59), *t* = 2013 and 2018.

$\mathbf{w}^{mx.t} = (\omega_1^{mx.t}, \dots \omega_i^{mx.t}, \dots \omega_{59}^{mx.t})$

$\omega_i^{mx.t} = w_i^{mx.t} / l_i^{mx.t}$ (1.7)

where: $\omega_i^{mx.t}$ = wage rate in industry *i* in time *t*, $w_i^{mx.t}$ = wages in industry *i* in current US dollars in time *t*; $l_i^{mx.t}$ = labor units in industry *i* in time *t*; *i* = (1, ...59); *t* = 2013 and 2018

$\mathbf{r}^{mx.t} = (r_i^{mx.t}, \dots r_i^{mx.t} \dots r_{59}^{mx.t})$

$r_i^{mx.t} = E_i^{mx,t} + T_i^{mx,t} / K_i^{mx,t}$ (1.8)

where: $r_i^{mx.t}$ = profit rate in industry *i* in time *t*, $E_i^{mx,t}$ = net profits by industry *i*, in US dollars in time *t*, $T_i^{mx,t}$ = production taxes by industry *i*, in US dollars in time *t*, $K_i^{mx,t}$ = productive capital by industry *i* in US dollars in time *t*; *i* = (1, ...59); *t* = 2013 and 2018.

$\mathbf{p}'^{mx.t} = \mathbf{v}'^{mx.t}\ \hat{\mathbf{w}}^{mx.t}\, (\mathbf{I} - \mathbf{H}^{mx.t}\, \hat{\mathbf{r}}^{mx.t})^{-1}$ (1.9)

where: $\mathbf{p}'^{mx.t}$ = row vector of prices in US dollars in time *t* ; $\mathbf{v}'^{mx.t}$ = vertically integrated labor per unit of output vector in time *t*; $\hat{\mathbf{w}}^{\mathbf{mx.t}}$ = diagonal matrix of wage rates; $\mathbf{H}^{mx.t}$ = vertically integrated capital goods coefficient matrix in time *t*; and $\hat{\mathbf{r}}^{mx.t}$ = diagonal matrix of profit rates in time *t*; *t* = 2013 and 2018.

For the estimation of productivity we have,

$\mathbf{a}'^{mx.t}$ = row vector of industries productivities in the Mexican economy in time *t*

$\mathbf{a}'^{mx.t} = (a_1^{mx.t}, \dots a_j^{mx.t} \dots a_{59}^{mx.t})$

$a_j^{mx.t} = l_j^{mx,t} / x_j^{mx,t}$

where: $l_j^{mx,t}$ = labor units by industry *j* in time *t* and $x_j^{mx,t}$ = gross output in constant Mexican pesos (base 2013) by industry *j* in time *t*;

Thus, the growth rate of productivity in our applied model is given by,

$-\varrho = (\ln \mathrm{a}_{2018} - \ln \mathrm{a}_{2013})/\,5$

where: final year is 2018 and initial year 2013, the time period is five and the data is annual data.

Notice that in the case of productivity we measured gross output at constant 2013 prices in Mexican pesos, instead of current US dollars, to eliminate de bias effect of depreciation that occurred in that period. Gross output measured at constant prices is the best approximation to a measure of output in terms of quantities. We are trying in this case to measure the ratio labor in physical units to output in physical units.

4.2 Applied model to the US economy

Also, as before, we define for the US economy the following variables and equations, where the subscript/superscript ***us*** stands for the United States.

$$\mathbf{x}^{\boldsymbol{us.t}} = \left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}{}_{\boldsymbol{us,t}}\right)^{-\mathbf{1}} \mathbf{y}^{\boldsymbol{us.t}} \tag{2.1}$$

where: $\mathbf{x}^{\boldsymbol{us.t}}$ = annual gross output in current US dollars in time *t*; $\mathbf{y}^{\boldsymbol{us.t}}$ = final demand in US current dollars in time *t*; $\mathbf{A}^{\boldsymbol{\theta}}$ = coefficient matrix of circulating and fixed capital in time *t*; *t* = 2013 and 2018.

$$\mathbf{A}^{\boldsymbol{\theta}}{}_{\boldsymbol{us,t}} = \mathbf{A}_{\boldsymbol{us,t}} + \mathbf{A}^{\mathbf{F}}{}_{\boldsymbol{us,t}} \cdot \widehat{\boldsymbol{\delta}}_{\boldsymbol{us,t}} \tag{2.2}$$

where: = $\mathbf{A}_{\boldsymbol{us,t}}$ = Input-output coefficient matrix in time *t*, $\mathbf{A}^{\mathbf{F}}{}_{\boldsymbol{us,t}}$ = coefficient matrix of fixed capital in time *t*; $\widehat{\boldsymbol{\delta}}_{\boldsymbol{us,t}}$ = diagonal matrix of depreciation rates.

$$\boldsymbol{\delta}^{\boldsymbol{us.t}} = (\delta_1^{us.t}, \dots, \delta_i^{us.t}, \dots, \delta_{59}^{us.t}) \tag{2.3}$$

$\delta_i^{\,us,t} = \; d_i^{\,us,t}/K_i^{\,us,t}$

where: $\delta_i^{us,t}$ = depreciation rates vector in time *t*; $d_i^{us,t}$ = depreciation values in industry *i* in current US dollars in time *t*; $K_i^{us,t}$ = productive capital in industry *i* in current US dollars in time *t*; *i* = (1, ... ,59), *t* = 2013 and 2018.

$$\mathbf{H}^{\boldsymbol{us.t}} = \mathbf{A}_{\boldsymbol{us,t}} \left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}{}_{\boldsymbol{us,t}}\right)^{\mathbf{-1}} \tag{2.4}$$

where: $\mathbf{H}^{\boldsymbol{us.t}}$ = vertically integrated capital goods matrix in current US dollars in time *t; t* = 2013 and 2018.

$$\mathbf{v}'^{\boldsymbol{us.t}} = \mathbf{a}'^{\boldsymbol{us.t}} \left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}{}_{\boldsymbol{us,t}}\right)^{\mathbf{-1}} \tag{2.5}$$

where: $\mathbf{v}'^{\boldsymbol{us.t}}$ = vertically integrated labor per unit of output vector in time *t*, and $\mathbf{a}'^{\boldsymbol{us.t}}$ = labor coefficients vector in time *t*; *t* = 2013 and 2018.

$$\mathbf{a}'^{\boldsymbol{us.t}} = (\mathrm{a}_1^{us.t}, \ldots \mathrm{a}_i^{us.t} \ldots\ \mathrm{a}_{59}^{us.t}\ )$$

$$\mathrm{a}_j{}^{us,t} = l_j{}^{us,t}/x_j{}^{us,t} \tag{2.6}$$

where: = $\mathrm{a}_j{}^{us,t}$ labor coefficients in industry *j* in time *t*; $l_j{}^{us,t}$ = labor units by industry *j* in time *t* and $x_j{}^{us,t}$ = gross output by industry *j* in current US dollars, in time *t*; *j* = (1...59), *t* = 2013 and 2018.

$$\mathbf{w}^{\boldsymbol{us.t}} = (\omega_1^{us.t}, \ldots \omega_i^{us.t}, \ldots \omega_{59}^{us.t})$$

$$\omega_i^{us.t} = w_i{}^{us.t}/l_i{}^{us.t} \tag{2.7}$$

where: $\omega_i^{us.t}$ = wage rate in industry *i* in time *t*; $w_i{}^{us.t}$ = wages in industry *i* in current US dollars in time *t*; $l_i{}^{us.t}$ = labor quantity in industry *i* in time *t*; *i* = (1, ...59); *t* = 2013 and 2018.

$$\mathbf{r}^{\boldsymbol{us.t}} = (r_i^{us.t}, \ldots\ r_i^{us.t} \ldots r_{59}^{us.t})$$

$$r_i^{us.t} = E_i{}^{us,t} + T_i{}^{us,t}/K_i{}^{us,t} \tag{2.8}$$

where: $= r_i^{us.t}$ profit rate in industry i in time t, ${E_i}^{us,t}$ = net profits in industry i, in US dollars in time t, ${T_i}^{us,t}$= production taxes in industry i, in US dollars in time t, ${K_i}^{us,t}$ = productive capital in industry i in US dollars in time t; $i = (1, ...59)$; t = 2013 and 2018.

$$\mathbf{p}'^{us.t} = \mathbf{v}'^{us.t}\, \hat{\mathbf{w}}^{us.t}\, (\mathbf{I} - \mathbf{H}^{us.t}\, \hat{\mathbf{r}}^{us.t})^{-1} \qquad (2.9)$$

where: $\mathbf{p}'^{us.t}$ = raw vector of prices in US dollars in time t ; $\mathbf{v}'^{us.t}$= vertically integrated labor per unit of output in time t; $\hat{\mathbf{w}}^{us.t}$ = diagonal matrix of wage rates in time t; $\mathbf{H}^{us.t}$= vertically integrated capital goods coefficient matrix in time t, and $\hat{\mathbf{r}}^{us.t}$ = diagonal matrix of profit rates in time t; t = 2013 and 2018.

For productivities in the US, we have:

$\mathbf{a}'^{us.t}$ = row vector of industries' productivities in the US economy in time t

$$\mathbf{a}'^{us.t} = (\mathrm{a}_1^{us.t}, \ldots \mathrm{a}_i^{us.t} \ldots \mathrm{a}_{59}^{us.t})$$

$${\mathrm{a}_j}^{us,t} = {l_j}^{us,t} / {x_j}^{us,t}$$

where: $= {a_j}^{us,t}$ labor coefficients in industry j in time t; ${l_j}^{us,t}$ = labor units by industry j in time t and ${x_j}^{us,t}$ = gross output by industry j in constant US dollars (base 2013) in time t.

Again, as in the case of Mexico, for productivity in the US we measured gross output at constant 2013 prices in US dollars, instead of current US dollars. The reason being that gross output measured at constant prices is the best approximation to a measure of output in terms of quantities and if we take this type of measurement for gross output for Mexico, we used it for the US too. So, we can make consistent comparison of productivity measurements between these countries.

The growth rate of productivity in our applied model is given by,

$$-\varrho = (\ln \mathrm{a}_{2018} - \ln \mathrm{a}_{2013}) / 5$$

where: final year is 2018 and initial year 2013, the time period is five and the data is annual data.

4.3 The terms of trade between México and the US

Pasinetti defines the *Terms of Trade* as the "ratio of the (weighted) average prices of exports to the (weighted) average prices of imports"(1981). Now in this case of Mexico-US bilateral trade instead of using Mexican imports from the US, we are using US exports to Mexico, in the same currency and time, which is really the same thing.

We first define a subset of industries (23) that produce traded goods in both countries from the set of industries (59) included in the US and Mexico matrices. We call this subset $CT_{mx.US}$ which includes both exports from US to Mexico and vice versa. The number of industries will be *m*. Notice that *m* = 23 while *n* =59. Then, we define ε_i^{US} = exports of industry *i* from the US to Mexico and ε_i^{mx} = exports of industry *i* from Mexico to the US. So, $\varepsilon_i^{US} \cup \varepsilon_i^{mx} = CT_{mx.US}$.

Given that in this period 2013-2018 and in this level of aggregation, there is trade both ways in all 23 industries considered in $CT_{mx.US}$. We take as ε_i^{US} and ε_i^{mx} the exports of the US to Mexico and the exports from Mexico to the US in 2013 and 2018, all from the same group of industries (23) that correspond to the $CT_{mx.US}$.

For Mexico's exports prices we define:

$$\mathbf{p}_{e.w.t}^{mx.\,\prime} = \mathbf{p}_{e.t}^{mx\prime} \cdot \hat{\boldsymbol{\varepsilon}}_{w.t}^{mx} \qquad (3.1)$$

where: $\mathbf{p}_{w.t}^{mx.\prime}$ = weighted exports price raw vector from Mexico to the US in time *t*, $\mathbf{p}_{e.t}^{mx\prime}$ = raw vector of export prices Mexico-US in time *t* ; $\hat{\boldsymbol{\varepsilon}}_{w.t}^{mx}$ = diagonal matrix of Mexican exports to the US weights in time *t*. *i* = (1,...23), *t* = 2013 and 2018 for weights and prices.

$$\boldsymbol{\varepsilon}_{w.t}^{\prime mx} = (\varepsilon_{w.t1}^{mx}, \dots \varepsilon_{w.t.i}^{mx} \dots , \varepsilon_{w.t.23}^{mx})$$

$\varepsilon^{mx}_{w.t.i} = \varepsilon^{mx}_{i.t} / \ \Sigma\, \varepsilon^{mx.t}_{i.t}$ (3.2)

where: $\varepsilon^{mx}_{w.t}$ = Mexican exports to the US weights per industry in time t; $\varepsilon^{mx}_{i.t}$= exports Mex-US in current US dollars in industry i, in time t; i = (1...23), t = 2013 and 2018.

$\mathbf{p}^{\boldsymbol{mx}\prime}_{\boldsymbol{e.t}} = (p^{mx}_{e.1.t}, \dots\ p^{mx}_{e.i.t} \dots p^{mx}_{e.23.t})$ These raw vector of export prices is part of the whole vector of prices $\mathbf{p}^{\prime\boldsymbol{mx.t}}$ in equation (1.9). Equivalently,

$\mathbf{p}^{\boldsymbol{mx.}\,\prime}_{\boldsymbol{e.w.t}} = (p^{mx}_{e.w.1.t}, \dots\ p^{mx}_{e.wi.t} \dots p^{mx}_{e.w.23.t})$

We know that **i** is a vector of ones in this case a column vector. So, we can obtain the following:

$\bar{\mathrm{p}}^{\boldsymbol{mx.}}_{\boldsymbol{e.w.t}} = \mathbf{p}^{\boldsymbol{mx.}\,\prime}_{\boldsymbol{e.w.t}} \cdot \mathbf{i}$ (3.3)

where: $\bar{\mathrm{p}}^{\boldsymbol{mx.}}_{\boldsymbol{e.w.t}}$ = weighted average of exports prices Mexico-US in time t; $\mathbf{p}^{\boldsymbol{mx.}\,\prime}_{\boldsymbol{e.w.t}}$ =row vector of exports prices of Mexico-US; **i** = summation column vector of order 1x13.

For the US exports prices, we define:

$\mathbf{p}'^{\boldsymbol{us}}_{e.w.t} = \mathbf{p}'^{\boldsymbol{us}}_{t} \cdot \hat{\boldsymbol{\varepsilon}}^{\boldsymbol{us}}_{w.t}$ (3.4)

where: $\mathbf{p}'^{\boldsymbol{us.}}_{\boldsymbol{e.w.t}}$ = weighted exports from US to Mexico, price vector in time t, $\mathbf{p}'^{\boldsymbol{us}}_{e.t}$ = row vector of exports prices from the US to Mexico; $\hat{\boldsymbol{\varepsilon}}^{\boldsymbol{us}}_{w.t}$= diagonal matrix of US exports to Mexico weights in time t. i = (1,...23), t = 2013 and 2018 for weights and prices.

$\boldsymbol{\varepsilon}'^{us}_{w.t} = (\varepsilon^{us}_{w.t.1}, \dots \varepsilon^{us}_{w.t.i}, \dots, \varepsilon^{us}_{w.t.10})$

$\varepsilon^{us.t}_{w.i} = \varepsilon^{us}_{i.t} / \Sigma\, \varepsilon^{us}_{i.t}$ (3.5)

where: $\varepsilon^{us.t}_{w}$ = US exports weights by industry in time t; $\varepsilon^{us.t}_{i}$= exports US-Mex in current US dollars in industry i, in time t; i = (1...23), t = 2013 and 2018.

$\mathbf{p}'^{\boldsymbol{us}}_{e.t} = (p^{us}_{e.1.t}, \dots\ p^{us}_{e.i.t} \dots p^{us}_{e.23.t})$ These raw vector of export prices is part of the whole vector of prices $\mathbf{p}'^{\boldsymbol{us.t}}$ in equation (2.9). Equivalently,

$\mathbf{p}'^{\boldsymbol{us}}_{\boldsymbol{e}.w.t} = (p^{us}_{e.w.1.t}, \dots\ p^{us}_{e.wi.t} \dots p^{us}_{e.w.23.t})$

We know that **i** is a vector of ones in this case a column vector. So, we can obtain the following:

$$\bar{\mathrm{p}}_{\boldsymbol{e.w.t}}^{\boldsymbol{us.}} = \mathbf{p}_{\boldsymbol{e.w.t}}^{\boldsymbol{us.}}{}' \cdot \mathbf{i} \tag{3.6}$$

where: $\bar{\mathrm{p}}_{\boldsymbol{e.w.t}}^{us.}$ = weighted average of exports prices US-Mexico in time t ; $\mathbf{p}_{\boldsymbol{e.w.t}}^{us}{}'$ =row vector of exports prices of Mexico-US; **i** = summation column vector of order 1 x 23.

Terms of trade equation

$$\mathbf{TT}_t^{mx.us} = \bar{\mathrm{p}}_{e.w.t}^{mx.} \;/\; \bar{\mathrm{p}}_{e.w.t}^{us.} \tag{3.7}$$

where: $\mathbf{TT}\,_t^{\boldsymbol{mx.us}}$ = Terms of Trade Mexico-US in time t; t = 2013 and 2018.

4.4 Ratios of Productivities' rates of growth between the US and México

Now we have to obtain the values of ϱ_{US} , ϱ_{mx} , R_{US} and R_{mx}. As before, wet define a subset of industries (23) that produce traded goods in both countries from the set of industries (59) included in the US and Mexico matrices. We call this subset CT$_{mx.US}$ which includes both exports from US to Mexico and vice versa. The number of industries will be m = 23. Then, we define ε_i^{us} = exports of industry i from the US to Mexico and ε_i^{mx} = exports of industry i from Mexico to the US. So, $\varepsilon_i^{us} \cup \varepsilon_i^{mx}$ = CT$_{mx.US}$

For Mexico, we define:

$\boldsymbol{\varrho}_{\boldsymbol{e.i.p}}^{\boldsymbol{mx}}{}'$ = raw vector of growth rates of productivity in industries exporting to the US from Mexico US in the period 2013 to 2018.

$$\boldsymbol{\varrho}_{e.p.i}^{mx}{}' = (\varrho_{e.p.1}^{mx},..\ \varrho_{e.p.i}^{mx},...\varrho_{e.p.m}^{mx})$$

$$\boldsymbol{\varrho}_{e.p.i}^{mx} = \boldsymbol{\varrho}_{e.i}^{mx\prime} \cdot \boldsymbol{\varepsilon}_{\boldsymbol{w.t}}^{mx} \tag{4.1}$$

where: $\varrho_{e.p}^{mx}$ = weighted average growth rate of productivity in industries exporting to the US from Mexico, in period p; $\boldsymbol{\varrho}_{e.p.i}^{mx}{}'$ = raw vector of productivity growth rates in industries exporting to the US from Mexico, in period p; $\boldsymbol{\varepsilon}_{\boldsymbol{w.t}}^{mx}$ = column vector of exports to the US from Mexico weights, in time *t*. Subscripts: *e* =exports *p* = period 2013 to 2018, *i* = industry (1..., *m*), *w* = weight, *t* = 2018.

For weights we have:

$\boldsymbol{\varepsilon}_{w.t}^{mx\prime}$ = ($\varepsilon_{w.1.t}^{mx}$,.. $\varepsilon_{w.i.t}^{mx}$,.. $\varepsilon_{w.m.t}^{mx}$) raw vector of exports weights for Mexico, in time *t*.

$$\varepsilon_{w.i.t}^{us} = \varepsilon_{i.t}^{us} \,/ \textstyle\sum_{i=1}^{m} \varepsilon_{i.t}^{us} \qquad (4.2)$$

where: $\varepsilon_{i.t}^{mx}$ = exports from Mexico to the US in each exporting industry *i* in current dollars in time *t*; *i* = (1...*m*) *t* =2018

For estimating R_p^{mx}, we have:

$\boldsymbol{\varrho}_{c.p.i}^{mx\,\prime}$ = raw vector of growth rates of productivity in common trading industries subset *c* in Mexico, in period *p*. Subscripts, *c* = $\mathrm{CT}_{mx.US}$ *p* = 2013–2018, *i* = (1, ..., *m*).

$$\boldsymbol{\varrho}_{c.p.i}^{mx\,\prime} = (\varrho_{c.p.1}^{mx},..\ \varrho_{c.p.i}^{mx},\ ...,\ \varrho_{c.p.m}^{mx}) \qquad (4.3)$$

For weights we have:

$\boldsymbol{\varepsilon}_{w.t}^{mx\prime}$ = ($\varepsilon_{w.1.t}^{mx}$,.. $\varepsilon_{w.i.t}^{mx}$,.. $\varepsilon_{w.m.t}^{mx}$) raw vector of exports weights for Mexico, in time *t*.

$$\varepsilon_{w.i.t}^{us} = \varepsilon_{i.t}^{us} \,/ \textstyle\sum_{i=1}^{m} \varepsilon_{i.t}^{us} \qquad (4.4)$$

where: $\varepsilon_{i.t}^{mx}$ = exports from Mexico to the US in each exporting industry *i* in current dollars in time *t*; *i* = (1...*m*) *t* =2018

Thus, we get,

$$R_p^{mx} = \boldsymbol{\varrho}_{c.p.i}^{mx\,\prime} \cdot \boldsymbol{\varepsilon}_{w.t}^{mx} \qquad (4.5)$$

where: R_p^{mx} = weighted average growth rate of productivity in common trading industries subset *c* in Mexico in period *p*; $\boldsymbol{\varrho}_{c.p.i}^{mx\,\prime}$ = raw vector of rates of growth of productivity in common trading industries in Mexico, in period *p*; $\boldsymbol{\varepsilon}_{w.t}^{mx}$ = column vector of exports weights of common trading industries in Mexico in time *t*. Subscripts: *c* = $\mathrm{CT}_{mx.US}$, *p* = 2013-2018, *t* = 2018.

For the US we define:

$\boldsymbol{\varrho}_{\boldsymbol{e.i.p}}^{us}{}'$ = raw vector of growth rates of productivity in industries exporting to Mexico from the US in the period 2013 to 2018.

$\boldsymbol{\varrho}_{e.p.i}^{us}{}' = (\varrho_{e.p.1}^{us}, .. \varrho_{e.p.i}^{us}, ... \varrho_{e.p.m}^{us})$

$$\varrho_{e.p.i}^{us} = \boldsymbol{\varrho}_{e.i}^{us}{}' \cdot \boldsymbol{\varepsilon}_{\boldsymbol{w.t}}^{us} \quad (4.6)$$

where: $\varrho_{e.p.i}^{us}$ = weighted average growth rate of productivity in industries exporting to Mexico from the US in period *p* (a scalar); $\boldsymbol{\varrho}_{e.p.i}^{us}{}'$ = raw vector of productivity growth rates in industries exporting to Mexico from the US in period *p*; $\boldsymbol{\varepsilon}_{\boldsymbol{w.t}}^{us}$ = column vector of exports from the US to Mexico weights, in time *t*. Subscripts: *e* =exports *p* = period 2013 to 2018, *i* = industry (1..., *m*), *w* = weight, *t* = 2018.

For the weights we have:

$\boldsymbol{\varepsilon}_{w.t}^{us}{}' = (\varepsilon_{w.1.t}^{us}, .. \varepsilon_{w.i.t}^{us}, .. \varepsilon_{w.m.t}^{us})$ raw vector of exports weights for the US, in time *t*.

$$\varepsilon_{w.i.t}^{us} = \varepsilon_{i.t}^{us} / \textstyle\sum_{i=1}^{m} \varepsilon_{i.t}^{us} \quad (4.7)$$

where: $\varepsilon_{i.t}^{us}$ = exports in each exporting industry to Mexico from US, in current dollars in time *t*; *i* = (1...*m*) *t* =2018.

For estimating R_p^{us}, we have:

$\boldsymbol{\varrho}_{c.p.i}^{us}{}'$ = raw vector of growth rates of productivity in common trading industries subset *c* in the US, in period *p*. Subscripts, $c = CT_{mx.US}$ *p* = 2013-2018, *i* = (1, ..., *m*).

$$\boldsymbol{\varrho}_{c.p.i}^{us}{}' = (\varrho_{c.p.1}^{us}, ... \varrho_{c.p.i}^{us}, ... \varrho_{c.p.m}^{us}) \quad (4.8)$$

For the weights we have:

$\boldsymbol{\varepsilon}_{w.t}^{us}{}' = (\varepsilon_{w.1.t}^{us}, .. \varepsilon_{w.i.t}^{us}, .. \varepsilon_{w.m.t}^{us})$ raw vector of exports weights for the US, in time *t*.

$$\varepsilon_{w.i.t}^{us} = \varepsilon_{i.t}^{us} / \textstyle\sum_{i=1}^{m} \varepsilon_{i.t}^{us} \quad (4.9)$$

where: $\varepsilon_{i.t}^{us}$ = exports in each exporting industry to Mexico from US, in current dollars in time t; i = (1...m) t =2018.

Thus, we have,

$$R_p^{us} = \boldsymbol{\varrho}_{c.p.i}^{us}{}' \cdot \boldsymbol{\varepsilon}_{\boldsymbol{w.t}}^{us} \quad (4.10)$$

where: R_p^{us} = weighted average growth rate of productivity in common trading industries subset c in the US in period p; $\boldsymbol{\varrho}_{c.p.i}^{us}{}'$ = raw vector of rates of growth of productivity in common trading industries in the US in period p; $\boldsymbol{\varepsilon}_{\boldsymbol{w.t}}^{us}$ = column vector of exports from the US to Mexico weights, in time t. Subscripts: e =exports p = period 2013 to 2018, i = industry (1..., m), w = weight, t = 2018.

With these equations we obtain the two crucial ratios to be compared. One for the US, $\varrho_{e.p.i}^{us}$ / R_p^{us} the other for Mexico, $\varrho_{e.p.i}^{mx}$ / R_p^{mx}

5. Results

5.1 Estimated variables

One issue to begin with is the not very surprising finding that the industries exporting from Mexico to the US, at the level of aggregation taken from official data, are exactly the same as those which export from the US to Mexico. So, the common trading group of industries is the same as the group of exporting countries to one another. It includes 23 industries, not considering services, which were not included in this analysis. This is shown in Table 1.

Thus, we must be more precise in establishing exports from one country to the other because all industries export about the same, and in a few cases, similar amounts. If we want to rigorously evaluate any specialization in trade, we must consider *net exports*. In this case, Mexico's net exports to the US come from 14 industries, and the net US exports to Mexico come from 9 industries. This, of course, indicates heavy inter-industry trading, which can be explained by the degree of integration of the Mexican economy with the US economy, in turn due to the free trade agreement that started in 1995.

Table 1

EXPORTS BY INDUSTRY BETWEEN MEXICO AND THE US

Millons of US current dollars

	SCIAN Codes	Industries	Exports Mexico-US		Exports US-Mexico	
			2013	2018	2013	2018
1	111-12	Farms	8,344.4	12,494.1	6,952.4	8,063.1
2	113-14-15	Forestry, fishing, and related activities	159.0	202.9	470.2	393.7
3	211	Oil and gas extraction	30,941.6	0.0	0.0	78.4
4	212	Mining, except oil and gas	3,223.6	2,106.6	1,371.7	1,250.2
5	220	Utilities	153.4	119.0	73.6	319.1
6	311-12	Food, beverage, and tobacco products	9,862.4	13,330.1	11,965.8	11,125.9
7	313-14	Textile mills and textile product mills	1,813.6	3,060.6	3,903.6	709.8
8	315-16	Apparel and leather and allied products	5,306.3	2,624.5	931.2	666.1
9	321	Wood products	374.8	465.0	651.6	723.6
10	322	Paper products	1,354.5	1,763.7	5,257.1	5,539.7
11	323	Printing and related support activities	386.6	352.7	646.1	652.3
12	324	Petroleum and coal products	5,055.4	1,683.3	21,531.9	5,307.8
13	325	Chemical products	5,086.1	6,341.3	27,762.1	32,942.5
14	326	Plastics and rubber products	5,502.4	7,150.6	8,837.0	10,047.8
15	327	Nonmetallic mineral products	2,827.9	3,295.0	1,296.1	1,548.9
16	331	Primary metals	8,809.1	9,037.6	9,718.4	10,512.6
17	332	Fabricated metal products	8,494.3	10,918.2	9,270.6	9,913.8
18	333	Machinery	21,837.5	27,633.0	15,674.2	16,203.3
19	334	Computer and electronic products	63,073.1	73,202.8	12,827.1	11,959.3
20	335	Electrical equipment, appliances, and components	22,484.6	27,759.5	11,400.5	12,368.7
21	336	Transport equipment	84,190.6	120,761.6	17,944.0	22,548.3
22	337	Furniture and related products	1,782.9	2,364.9	443.1	441.2
23	339	Miscellaneous manufacturing	7,420.0	9,914.1	2,801.7	3,150.0

Source: Instituto Nacional de Geografía y Estadística (INEGI) México

In Table 2, we show the set of prices in each industry for Mexico in 2013 and 2018 that resulted from the corresponding equation of the applied model. The weights used are the exports from Mexico to the US based on official data.

In Table 3, we show the sets of prices in each industry for the US in 2013 and 2018 in Mexico. The weights used are the exports from the US to Mexico based on official data.

Table 2

WEIGHTED PRICES OF MEXICAN EXPORTS GOODS TO THE US 2013 AND 2018

	SCIAN Codes	Trading indutstries	2013 Prices Thou. Dlls	2013 Exports Mills Dlls	2013 Weights %	2013 Weigthed Prices	2018 Prices Thou. Dlls	2018 Exports Mills Dlls	2018 Weights %	2018 Weigthed Prices
1	111-12	Farms	21.95	8,344.4	2.80	0.614	20.68	12,494.1	3.7	0.768
2	113-14-15	Forestry, fishing, and related activities	72.50	159.0	0.05	0.039	45.13	202.9	0.1	0.027
3	211	Oil and gas extraction	36.79	30,941.6	10.37	3.814	38.61	0.0	0.0	0.000
4	212	Mining, except oil and gas	55.43	3,223.6	1.08	0.599	43.74	2,106.6	0.6	0.274
5	220	Utilities	48.02	153.4	0.05	0.025	21.75	119.0	0.0	0.008
6	311-12	Food, beverage, and tobacco products	94.00	9,862.4	3.30	3.106	38.46	13,330.1	4.0	1.523
7	313-14	Textile mills and textile product mills	53.36	1,813.6	0.61	0.324	18.03	3,060.6	0.9	0.164
8	315-16	Apparel and leather and allied products	66.05	5,306.3	1.78	1.174	24.72	2,624.5	0.8	0.193
9	321	Wood products	128.36	374.8	0.13	0.161	219.00	465.0	0.1	0.303
10	322	Paper products	47.14	1,354.5	0.45	0.214	29.94	1,763.7	0.5	0.157
11	323	Printing and related support activities	50.00	386.6	0.13	0.065	21.76	352.7	0.1	0.023
12	324	Petroleum and coal products	80.71	5,055.4	1.69	1.367	32.22	1,683.3	0.5	0.161
13	325	Chemical products	60.25	5,086.1	1.70	1.027	21.36	6,341.3	1.9	0.402
14	326	Plastics and rubber products	45.60	5,502.4	1.84	0.841	20.58	7,150.6	2.1	0.437
15	327	Nonmetallic mineral products	39.36	2,827.9	0.95	0.373	27.05	3,295.0	1.0	0.265
16	331	Primary metals	111.98	8,809.1	2.95	3.305	38.67	9,037.6	2.7	1.038
17	332	Fabricated metal products	51.31	8,494.3	2.85	1.460	14.68	10,918.2	3.2	0.476
18	333	Machinery	56.31	21,837.5	7.32	4.120	27.45	27,633.0	8.2	2.253
19	334	Computer and electronic products	59.39	63,073.1	21.13	12.549	32.91	73,202.8	21.7	7.158
20	335	Electrical equipment, appliances, and components	45.11	22,484.6	7.53	3.398	28.87	27,759.5	8.2	2.381
21	336	Transport equipment	61.85	84,190.6	28.21	17.445	32.00	120,761.6	35.9	11.480
22	337	Furniture and related products	74.71	1,782.9	0.60	0.446	19.80	2,364.9	0.7	0.139
23	339	Miscellaneous manufacturing	35.02	7,420.0	2.49	0.871	15.64	9,914.1	2.9	0.461
		Sums	1,395.19	298,484.1	100.00	57.334	833.04	336,581.3	100.00	30.091

Sources: Prices estimated by the model. Exports from INEGI México

Table 3

WEIGHTED PRICES OF US EXPORT GOODS TO MEXICO 2013 AND 2018

	SCIAN Codes	Trading industries	2013 Prices Thou. Dlls	2013 Exports Mills Dlls	2013 Weights %	2013 Weighted Prices	2018 Prices Thou. Dlls	2018 Exports Mills Dlls	2018 Weights %	2018 Weighted Prices
1	111-12	Farms	506.74	6,952.4	4.05	20.515	401.73	8,063.1	4.84	19.458
2	113-14-15	Forestry, fishing, and related activities	661.63	470.2	0.27	1.811	688.26	393.7	0.24	1.628
3	211	Oil and gas extraction	677.71	0.0	0.00	0.000	805.27	78.4	0.05	0.379
4	212	Mining, except oil and gas	715.25	1,371.7	0.80	5.713	703.22	1,250.2	0.75	5.281
5	220	Utilities	564.16	73.6	0.04	0.242	605.38	319.1	0.19	1.161
6	311-12	Food, beverage, and tobacco products	940.74	11,965.8	6.97	65.549	940.79	11,125.9	6.68	62.879
7	313-14	Textile mills and textile product mills	627.58	3,903.6	2.27	14.266	622.90	709.8	0.43	2.656
8	315-16	Apparel and leather and allied products	746.67	931.2	0.54	4.049	756.68	666.1	0.40	3.028
9	321	Wood products	929.10	651.6	0.38	3.525	961.26	723.6	0.43	4.178
10	322	Paper products	915.53	5,257.1	3.06	28.027	911.74	5,539.7	3.33	30.341
11	323	Printing and related support activities	832.08	646.1	0.38	3.131	830.91	652.3	0.39	3.256
12	324	Petroleum and coal products	1306.54	21,531.9	12.54	163.818	1403.94	5,307.8	3.19	44.765
13	325	Chemical products	896.11	27,762.1	16.17	144.867	771.99	32,942.5	19.79	152.773
14	326	Plastics and rubber products	891.04	8,837.0	5.15	45.852	827.63	10,047.8	6.04	49.955
15	327	Nonmetallic mineral products	745.58	1,296.1	0.75	5.627	793.85	1,548.9	0.93	7.386
16	331	Primary metals	836.26	9,718.4	5.66	47.325	837.16	10,512.6	6.32	52.868
17	332	Fabricated metal products	906.27	9,270.6	5.40	48.923	868.32	9,913.8	5.96	51.713
18	333	Machinery	1037.21	15,674.2	9.13	94.669	941.12	16,203.3	9.73	91.606
19	334	Computer and electronic products	764.17	12,827.1	7.47	57.078	633.05	11,959.3	7.18	45.480
20	335	Electrical equipment, appliances, and components	1022.84	11,400.5	6.64	67.903	950.46	12,368.7	7.43	70.621
21	336	Transport equipment	1194.18	17,944.0	10.45	124.779	1149.34	22,548.3	13.55	155.682
22	337	Furniture and related products	909.30	443.1	0.26	2.346	971.69	441.2	0.27	2.575
23	339	Miscellaneous manufacturing	980.28	2,801.7	1.63	15.993	920.86	3,150.0	1.89	17.425
		Sums	19,606.97	171,729.9	100.00	966.007	19,297.54	166,466.1	100.00	877.093

Sources: Prices estimated by the model. Exports from INEGI México

Productivities in Mexico and the US were calculated according to the equations in the models as the ratios of labor to gross output by industry. In both cases, we utilized data of real gross output, which is gross output in constant 2013 prices. Then, the annual rates of growth of these productivities for all industries from 2023 to 2018 were calculated and are shown in Table 4.

Table 4
PRODUCTIVITIES RATES OF GROWTH IN COMMON SECTORS
IN MEXICO AND THE US
Annual rates 2018/2013 in percentages

	SCIAN	Industries/Sectors	Mexico	US
1	111-12	Farms	-0.192	-0.109
2	113-14-15	Forestry, fishing, and related activities	-0.008	0.002
3	211	Oil and gas extraction	0.000	-0.005
4	212	Mining, except oil and gas	-0.076	-0.001
5	220	Utilities	-0.003	0.000
6	311-12	Food, beverage, and tobacco products	-0.264	0.102
7	313-14	Textile mills and textile product mills	0.068	0.004
8	315-16	Apparel and leather and allied products	-0.062	-0.003
9	321	Wood products	-0.007	-0.001
10	322	Paper products	-0.039	0.015
11	323	Printing and related support activities	-0.010	-0.003
12	324	Petroleum and coal products	-0.012	-0.034
13	325	Chemical products	-0.183	0.403
14	326	Plastics and rubber products	-0.336	0.037
15	327	Nonmetallic mineral products	-0.077	0.005
16	331	Primary metals	-0.291	0.035
17	332	Fabricated metal products	-0.385	0.018
18	333	Machinery	-0.560	0.180
19	334	Computer and electronic products	-0.004	-0.168
20	335	Electrical equipment, appliances, and components	-0.803	0.089
21	336	Transport equipment	-4.784	-0.057
22	337	Furniture and related products	-0.042	0.002
23	339	Miscellaneous manufacturing	-0.145	0.040
		Weighted sums	-8.215	0.553

Note: A negative rate means an increase in productivity in this case
Source: Estimations from the model

The estimated values of the productivity rates of growth for the specialized industries (i.e., the net exporting industries) in each country are shown in Table 5.

Table 5			
PRODUCTIVITIES GROWTH RATES IN SPECIALIZED SECTORS			
Annual rates 2018/2019 in percentages			
	SCIAN	Industries/Sectors	**Mexico**
1	111-12	Farms	-0.192
2	211	Oil and gas extraction	0.000
3	212	Mining, except oil and gas	-0.076
4	311-12	Food, beverage, and tobacco products	-0.264
5	313-14	Textile mills and textile product mills	0.068
6	315-16	Apparel and leather and allied products	-0.062
7	327	Nonmetallic mineral products	-0.077
8	332	Fabricated metal products	-0.385
9	333	Machinery	-0.560
10	334	Computer and electronic products	-0.004
11	335	Electrical equipment, appliances, and components	-0.803
12	336	Transport equipment	-4.784
13	337	Furniture and related products	-0.042
14	339	Miscellaneous manufacturing	-0.145
		Weighted average	-7.326
	SCIAN	Industries/Sectors	**US**
1	113-14-15	Forestry, fishing, and related activities	0.002
2	220	Utilities	0.000
3	321	Wood products	-0.001
4	322	Paper products	0.015
5	323	Printing and related support activities	-0.003
6	324	Petroleum and coal products	-0.034
7	325	Chemical products	0.403
8	326	Plastics and rubber products	0.037
9	331	Primary metals	0.035
		Weighted average	0.455
Note: A negative rate means an increase in productivity in this case			
Source: Estimations from the model			

5.2 Results analysis

The resulting estimation (with data shown in Tables 2 and 3) of the Terms of Trade Mexico-US are: $\mathbf{TT}\,^{mx.us}_{2013} = 0.059$ and $\mathbf{TT}\,^{mx.us}_{2018} = 0.034$. These figures indicate that there was a variation in the Terms of Trade of -42.2 per cent in the period from 2013 to 2018. In principle, this proves Pasinetti's hypothesis of terms of trade deterioration for the undeveloped country in this period.

With respect to the productivity ratios, the results in Tables 4 and 5 can be summarized as follows:

Productivity rates of growth 2018/2013

	Mexico	**US**
Exporting industries	-7.326	0.455
Common trading industries	-8.215	0.553

It should be noted that a negative value in the rate of growth of these productivity rates means a positive variation in productivity (less labor for more or the same output). If the value is positive, it means exactly the opposite, i.e., a reduction in the productivity ratio.

To begin with, we observe in the results that Mexico increased its productivity in this period on average in both the exporting industries and the common trading industries. In contrast, the US saw a slight decline in average productivity in both the exporting industries and the common trading industries.

The ratios we are looking for in this study can now be clearly understood. Being ϱ_{us} the average rate of growth of productivity in the US in the exporting industries, and R_{us} the average rate of growth of common trading industries in the US; and ϱ_{mx} the average rate of growth of productivity in Mexico in the exporting industries and R_{mx} the average rate of growth of common trading industries in Mexico, we have:

ϱ_{us}/R_{us} = 0.455/0.553 = 0.822, and ϱ_{mx}/R_{mx} = -7.326/-8.215 = 0.892.

Therefore: ϱ_{us}/R_{us} = 0.822 $< \varrho_{mx}/R_{mx}$ = 0.892. This situation means, for Pasinetti (1981), leakages of productivity gains from Mexico to the US. Pasinetti regarded this particular case as the cause of the deterioration in the Terms of Trade for Mexico as observed.

5.3 Additional analyzed variables

To see another angle of the Mexico-US trade case, we present in Table 6 the comparison of labor compensations in Mexico and the US, in US current dollars per worker per year. Far from being equalized after more than twenty years of free trade between the two countries, they are clearly different in every trading industry: higher in the US and lower in Mexico. The ratio is 15 to one.

One important aspect is what happened in the period 2013 to 2018 to the exchange rate between the two currencies. According to the data of the Bank of Mexico, in 2013, the exchange rate of the Mexican peso to the US dollar was 12.77, and in 2018 it was 19.4. This represents a depreciation of 51.9 percent. There has been a free exchange rate market regime in Mexico since 1995, but the “equilibrium exchange rate” has never prevailed, for reasons beyond the scope of our study.

In any case, the main effect of the devaluation of the Mexican Peso to the US Dollar during this period was to reduce wages paid in Mexican Pesos. For US companies producing and exporting from Mexico, this meant an important way to reduce costs and increase profits.

Table 6

WAGES IN THE US AND MEXICO 2013 AND 2018

US Dollars per worker a year at current prices

		United States			Mexico			US/Mex
	Industries	2013	2018	AGR	2013	2018	AGR	2018
1	Farms	20,759	20,581	-0.17	888	836	-1.20	23.63
2	Forestry, fishing, and related activities	35,445	44,333	4.58	1,355	1,061	-4.77	40.77
3	Oil and gas extraction	186,826	211,624	2.52	51,767	43,435	-3.45	3.87
4	Mining, except oil and gas	89,671	100,111	2.23	8,200	9,031	1.95	10.09
5	Utilities	134,774	154,745	2.80	22,154	19,187	-2.83	7.06
6	Food, beverage, and tobacco products	57,474	63,323	1.96	4,055	3,365	-3.66	17.82
7	Textile mills and textile product mills	47,676	54,539	2.73	3,339	2,746	-3.83	18.86
8	Apparel and leather and allied products	44,054	51,404	3.13	3,111	3,278	1.05	14.68
9	Wood products	48,791	55,775	2.71	3,643	2,764	-5.37	19.18
10	Paper products	79,761	87,472	1.86	6,838	7,250	1.18	11.07
11	Printing and related support activities	54,813	61,175	2.22	4,192	4,804	2.76	11.73
12	Petroleum and coal products	169,045	177,696	1.00	49,590	29,457	-9.89	5.03
13	Chemical products	116,918	125,487	1.42	14,042	14,520	0.67	7.64
14	Plastics and rubber products	61,966	68,201	1.94	6,582	8,396	4.99	7.12
15	Nonmetallic mineral products	63,371	73,176	2.92	3,937	3,323	-3.34	21.02
16	Primary metals	78,348	91,091	3.06	12,817	12,947	0.20	6.04
17	Fabricated metal products	63,815	72,559	2.60	4,368	5,022	2.83	13.45
18	Machinery	80,840	90,994	2.39	11,289	10,149	-2.11	7.97
19	Computer and electronic products	121,687	151,757	4.52	12,364	8,928	-6.30	16.00
20	Electrical equipment, appliances, and components	88,995	95,982	1.52	9,689	10,122	0.88	8.48
21	Transport equipment	88,867	96,633	1.69	8,731	10,827	4.40	7.93
22	Furniture and related products	47,590	54,803	2.86	2,958	2,730	-1.59	19.07
23	Miscellaneous manufacturing	77,894	87,543	2.36	5,445	4,592	-3.35	18.06
	Total averages	80,349	91,003	2.54	10,561	9,196	-1.35	15.1

AGR Average Growth Rate

Sources: Data from INEGI for Mex and BEA for USA

Conclusions

Based on our careful application of Pasinetti's model to the case of Mexico-US trade from 2013 to 2018, we can conclude that Pasinetti's theories regarding trade between an advanced and a developing country fully apply to the US-Mexico case during this period. His main hypotheses were evaluated and confirmed: (1) there was a deterioration in the Terms of Trade for Mexico with the US from 2013 to 2018, and (2) productivity gains from Mexico leaked to the US.

Additionally, contrary to assumptions under accepted free trade theory, a wage gap persisted between the two countries. All of this occurred within the context of a trade balance favorable to Mexico since the establishment of a free trade agreement with the US. Lastly, we can affirm that Prebish's thesis of unequal exchange also holds true for this case in this period, despite Mexico no longer being mainly an exporter of primary goods as it once was.

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APPENDIX I

1. Pasinetti's pure production model and price system

$$\mathbf{x} = \left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}\right)^{-1} \mathbf{y} \tag{A.1}$$

where: $\mathbf{x}$ = gross output, $\mathbf{y}$ = final demand; $\mathbf{A}^{\boldsymbol{\theta}}$ = coefficient matrix of circulating and fixed capital.

$$\mathbf{A}^{\boldsymbol{\theta}} = \mathbf{A} + \mathbf{A}^{\mathbf{F}} \cdot \widehat{\boldsymbol{\delta}} \tag{A.2}$$

where: $\mathbf{A}$ = coefficient matrix of circulating capital, $\mathbf{A}^{\mathbf{F}}$ = coefficient matrix of fixed capital; $\widehat{\boldsymbol{\delta}}$ = diagonal matrix of depreciation rates.

$$\boldsymbol{\delta} = (\delta_1, \dots, \delta_i, \dots, \delta_n)$$

$$\delta_i = d_i/K_i \tag{A.3}$$

where: δ_i = depreciation rate of industry i; d_i = depreciation values of industry i; K_i = productive capital of industry i; $i = (1, \dots, n)$.

$$\mathbf{H} = \mathbf{A}\left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}\right)^{-1} \tag{A.4}$$

where: $\mathbf{H}$ = vertically integrated capital goods matrix.

$$\mathbf{v}' = \mathbf{a}'\left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}\right)^{-1} \tag{A.5}$$

where: $\mathbf{v}'$ = vertically integrated labor and $\mathbf{a}'$ = labor coefficients vector.

$$\mathbf{a} = (\mathrm{a}_1, \dots \mathrm{a}_j \dots \mathrm{a}_n)$$

$$\mathrm{a}_j = l_j/x_j \tag{A.6}$$

where: a_j = labor coefficients in industry j; l_j = labor in industry j and x_j = gross output in industry j, $j = (1, \dots, n)$.

$$\mathbf{p}' = \mathbf{a}'\left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}\right)^{-1} w + \mathbf{p}'\,\mathbf{A}\left(\mathbf{I} - \mathbf{A}^{\boldsymbol{\theta}}\right)^{-1} r \tag{A.7}$$

where: $\mathbf{p}'$ = vector of prices; w = uniform wage rate, r = uniform profit rate.

So that any particular price is given by:

$p = \mathbf{v}\, w + \mathbf{p}'\mathbf{H}\, r$

At this point, we modified the assumption in Pasinetti's model of a uniform rate of profit, *r,* and a uniform wage rate *w* for all industries in the economy. In this case we estimate a vector of wage rates **w** and a vector of profit rates **r**.

$\mathbf{w} = (\omega_1, \dots \omega_i, \dots \omega_n)$

$\omega_i = w_i / l_i$ (A.8)

where: ω_i = wage rate in industry i, w_i = wages in industry i; l_i = labor units in industry i; i = (1, ..., n).

$\mathbf{r} = (r_1, \dots, r, \dots r_n)$

$r_i = E_i + T_i / K_i$ (A.9)

where: r_i= profit rate in industry i ; E_i= net profits in industry i, T_i = production taxes in industry i; K_i= productive capital in industry i; i = (1, ..., n).

So, we can transform equation (A.7) into:

$\mathbf{p}' = \mathbf{v}'\hat{\mathbf{w}} + \mathbf{p}'\mathbf{H}\,\hat{\mathbf{r}}$

where: $\mathbf{p}'$= price vector; $\hat{\mathbf{w}}$ = diagonal matrix of wage rates and $\hat{\mathbf{r}}$ = diagonal matrix of profit rates.

Then it is transformed into:

$\mathbf{p}'\,(\mathbf{I} - \mathbf{H}\hat{\mathbf{r}}) = \mathbf{v}'\hat{\mathbf{w}}$

And finally, we arrive to the price vector equation:

$\mathbf{p}' = \mathbf{v}'\hat{\mathbf{w}}\,\,(\mathbf{I} - \mathbf{H}\hat{\mathbf{r}})^{-1}$ (A.10)

APPENDIX II

DATA SOURCES AND WEB REFERENCES

Source of US economic data:

U.S. Bureau of Economic Analysis (BEA) https://bea.gov

https://www.bea.gov/data/special-topics/integrated-industry-level-production-account-klems

https://www.bea.gov/data/employment/employment-by-industry

https://www.bea.gov/data/industries/input-output-accounts-data

https://www.bea.gov/data/industries/gross-output-by-industry

https://www.bea.gov/data/intl-trade-investment/international-trade-goods-and-services

Source of Mexican economic data:

National Institute of Geography and Statistics https://en.www.inegi.org.mx/

https://www.inegi.org.mx/programas/tod/2018/

https://www.inegi.org.mx/programas/acervos/2018/

https://www.inegi.org.mx/programas/mip/2018/

https://www.inegi.org.mx/programas/cou/2018/

https://www.inegi.org.mx/app/indicadores/?tm=0

https://www.inegi.org.mx/app/indicadores/#

https://www.inegi.org.mx/programas/ptf/2018/