International Trade, Technology Gaps and Uneven Development

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Abstract

In North-South long-run equilibrium analysis, asymmetries in saving propensities are introduced as an explanatory factor behind the uneven distribution of income among countries and the concentration of wealth in the North. In this paper we use a simulation model in order to see whether analogous patterns of uneven development emerge in an evolutionary process with productivity asymmetries. The basic mechanisms of the model are price competition and labour saving technical change. To develop the argument, the paper presents a multiple-sector, multiple-firm simulation model in which trade and capital flows take place between two countries. The short-run dynamics of this model characterized by differences in efficiency at a firm level produces results that resemble in some respects those that emerge in the long-run dynamics of uneven development. Superior technological performance appears as a key factor for the countries' more aggressive accumulation pattern that is behind the uneven distribution of wealth and income. A simulation excersise is used to show how a country can be negatively affected by the pressure of the competitive struggle in the international market.

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1 Introduction

The idea that the process of economic change is characterized by patterns of uneven development and that international economic relationships play an important role in the unfolding of these patterns has a long tradition in economic thinking and can be traced to the debates among classical economists. The concept of "uneven development" is often associated to structuralist dependency economists, for which this theme is central, but under this or different headings it has also been an important research area in most schools of economic thought.

In formal modelling, under the generic title of North-South literature we find numerous contributions from the most diverse ascription dealing with topics related to uneven development. The greatest emphasis in the research agenda has been placed on analyzing the role of different asymmetries in explaining differences in economic growth and welfare. In relation to the role of international economic relations in shaping development, the focus has been on trade specialization and on its determinants. In the last decade, endogenous growth literature has placed technological change as a key variable within these analyses. Most often, for methodological reasons, modelling tends to focus on the search for the long run (static or dynamic) properties of the systems and on their implications in relation to convergence and divergence. In most cases, the requirements of analytical work has lead to simplifying assumptions and aggregate analysis that leave on the shade the role of micro diversity and short-run dynamics which are potentially important levels for an understanding of economic development.

Among the different approaches to the modelling of trade and development, the major contribution of the evolutionary (post-Schumpeterian) approach is precisely to look at the driving forces of the mechanisms of selection and creation of diversity within economic systems. In this way, evolutionary modelling provides insights on the endogenous nature of economic change. The unevenness of development and the focus on the role of technological change are at the very heart of this approach. In fact, a pure selection model of uneven development is already present in the seminal contribution of Nelson and Winter (Nelson, 1968, Nelson and Winter, 1982) which was so important for the 'take off' of modern evolutionary modelling along Schumpeterian lines.

A considerable amount of research has been done in the last two decades along the analytical and the simulation modelling strategies proposed by Nelson and Winter. The work dealing explicitly with international trade and economic development has provided important insights, among which the following are worth highlighting: 1) The mechanism of selection plays a

key role in the dynamics of technological change and can provide an explanation to changing patterns of comparative advantage (Metcalfe, 1989). 2) Differences in technological dynamism and consumption structure between countries can explain specialization and uneven patterns of growth. And 3) macro level relationships between trade and growth (such as Thirlwal's balance of payments constraint) can find "microfoudations" in sectoral dynamics driven by the interplay of selection and technological change (Verspagen, 1993). 4) The mechanisms that create technological diversity play a key role in the asymmetries that we observe at a country level. Therefore, starting from an entirely symmetric world, the differences introduced and widened by innovation at the micro level can generate patterns of trade and uneven development that resemble those observed empirically (Dosi et al., 1994). 5) In a bottom-up construction of an international economic system, domestic and international markets emerge from the specialization process triggered by technological change. At each stage of this development, new rules and institutions that emerge will be shaped by the interplay between technological progress and the rules that already exist (Andersen, 1999). The unevenness of development induces diversity in institutional arrangements.

No doubt, work stemming from other modelling approaches has also made valuable contributions to our understanding of different aspects of the development of trading economies. Of particular interest for those aspects that are analyzed in this paper is Mainwaring's (1991, 1993) enlightening analysis of uneven development which directs the attention to the dynamics of capital accumulation and world distribution of wealth. Mainwaring blends steady growth analysis within the post-Keynesian and neo-Ricardian traditions with a perspective of dynamics inspired in the work of Eigen (1971). By shifting the attention from the "very" long run steady growth properties of the model to the long-run dynamics, the spirit of the analysis converged to a great extent with that of the evolutionary perspective outlined above. Mainwaring extends Pasinetti's (1974) analysis of accumulation and growth in a closed economy to a world economy to obtain what it is labeled as the "International Pasinetti process" in which the thriftiest nation comes to dominate. The author examines numerous scenarios and reaches many intuitively plausible results, all of which would take too long to survey. We will limit ourselves to mention (using North-South terminology) two of the broad tendencies in the path to the steady state. 1) There is an increasing growth rate in both countries, and the rate in the South can be higher than in the North. 2) There is a tendency to the domination of the North over the South, which takes the form of a control of capital accumulation, and a concentration of world wealth ownership in the North. As we mentioned above, the key element behind the results of the model is the ranking of the average

savings propensities of the countries (with that of the North being higher). To the extent that the difference in saving propensities is the way in which the model captures the difference in the "aggressiveness" of capitalist accumulation, it is of interest to take the analysis to a more disaggregate level. This will allow us to explore other lower level asymmetries, processes and mechanisms that can generate such a difference in average aggressiveness.

In this paper we use an evolutionary simulation model in order to see whether analogous patterns of development to those of the "International Pasinetti process" explored by Mainwaring emerge in an evolutionary process with productivity asymmetries. The basic mechanisms of the model are price competition, which determines market shares and provides the resources to grow, and the productivity increases that result from technical change which reduce costs and also contribute to firm competitiveness and capital accumulation. To develop the argument, the paper presents a three-sector, multiple-firm simulation model in which trade and capital flows take place between two countries. In this simple environment of price competition and productivity-oriented technological change, the development of the international economy is characterized by uneven patterns of wealth and income distribution among countries. Thus, for short-run dynamics, a micro-founded simulation model characterized by differences in efficiency at a firm level produces results that resemble in some respects those that emerge in the long-run dynamics of uneven development, as a result of the asymmetry in the saving propensities between countries. The analysis makes evident that superior technological performance is one of the key factors for the countries' more aggressive accumulation pattern that is behind the uneven distribution of wealth and income. On the other hand, it also shows that economic activity of a country can be negatively affected by the pressure of the competitive struggle in the international market.

The paper suggests that looking at country level asymmetries as changing averages that arise from micro behaviour may help us to understand better the micro processes and institutional determinants of uneven development. The paper also suggests that, although simulation modelling may seem to be at a disadvantage with respect to more simple analytical models which may produce more clear-cut results, it has the advantage of providing a more integral approach to the interplay of complex relationships. Such a property of this modelling strategy is useful to unravel the interrelationships between the micro processes and the macro dimensions of the uneven patterns that we observe in economic development. Furthermore, these models can provide a useful reference to discuss alternative institutional arrangements at the national and the international levels and examine the convenience (or lack of it) of different settings depending on the kind of insertion of a country in

the international economy.

Section 2 of the paper describes the key aspects of the uneven development process that the model intends to capture. Section 3 explains the details of the model and the simplifying assumptions that have been introduced in order to simulate the process of uneven development. Section 4 describes a simulation exercise and the simulation results. Finally, section 5 presents the conclusions and comments both on the limitations of the model and on possible extensions.

2 Innovation, International Trade and Uneven Development

Although mainstream economic theory on international economic relations has produced some results that indicate the possibility of negative aspects arising from international economic relations, the general message of the bulk of the literature tends to highlight the long-run positive effects in terms of potential welfare and economic growth. Among the aspects highlighted in the literature are the gains arising from trade and specialization, spillovers from technological progress and tendencies to convergence in the rates of economic growth. The message is that even if there are international disparities, laggard countries are better off in absolute terms as the result of economic relations than remaining in isolation. Dependency literature, in contrast, portrayed the international dimension of capitalist development as a process of polarization in the world economy which divides it in North and South (or Centre and Periphery). In this account, the process of development is uneven and development of the South becomes increasingly dependent on the North. The aspects stressed in this literature are the external control and exploitation of the Southern economy by the North.

No doubt, the arguments about exploitation and one-sided dependence may be misleading. However, the merit of dependency literature was to emphasize that the high rates of unemployment, greater economic instability and social turmoil that characterizes developing countries overburdened by international debt are not independent of the nature of the insertion of these countries in the international economy. Even if the large differences and widening gaps in income and wealth in the international economy are not the result of a process of exploitation of one set of countries by another, they are not independent of their economic relations.

The crux of the argument that underlies this paper rest on two facts highlighted by Schumpeter in relation to capitalist development: it is both a

worldwide phenomena and it is a disruptive process of creative destruction. Capitalist competition is constantly producing winners and losers, and it does not distribute gains and losses evenly nor within a single country neither in the international arena.

The simulation model below tries to capture in a very simplified and stylized way some of the basic mechanisms of international economic relations that may contribute to place a country in a trap of underdevelopment and economic instability. Expressed in North -South terminology the mechanisms and processes that the model attempts to capture are the following: Superior technological performance (higher rate of increase in labour productivity) in the North may have an undermining effect in the economic activity of the South through the pressure of external competition on domestic producers. Substitution of foreign for domestic products generates trade disequilibria and international borrowing that turn into a heavy external debt burden for the South. Sooner or later this country has to become competitive enough to generate offsetting trade surpluses. And if the country were unable to do this, it would have to suppress this burden transferring the property of domestic assets to its debtors. Comparative advantage determines the patterns of specialization, but the possibility to generate trade surpluses depends on absolute cost reductions of domestic firms translating in lower prices. With inferior technological performance, the South can only achieve greater competitiveness by reducing the relative remuneration of domestic primary factors of production (labour in this model) since international capital mobility hinders the possibility of gaining competitiveness through a lower remuneration of capital. Currency devaluation is a mechanism to achieve greater competitiveness but it has a limited effect. First, because domestic primary factors are only one of the components of costs, and the price of imported means of production in domestic currency increases with devaluation. Second, because after devaluation, the cost of capital also increases in domestic currency. In addition, as the increase in costs translate to prices, workers press for an increase in wages trying to resist the erosion of their purchasing power, and domestic firms can only compete if wage increases are refrained. Momentary gains in competitiveness allow for temporary trade surpluses that for some time allow the South to face the burden of foreign debt. However, competitiveness is also eroded due to the external pressure of a technologically more dynamic North. Therefore, sooner or later, the external disequilibrium reappears. This situation of recurrent external disequilibria reaches a point where it is not possible for the South to cover with trade surpluses the service of foreign debt. The attempts to correct external disequilibrium end up having an adverse effect on macroeconomic stability.

In summary, the benefits for the South in the way of cheaper goods from

abroad, financed with international borrowing, may be offset by the negative effects of contraction of economic activity, compromising future output to pay for today's consumption. Neither devaluations, nor productivity gains in the South can revert this tendency unless they can be achieved at the same pace as they take place in the North. Even temporary isolation of the economy is of no use. Parallel to this process is a deepening of concentration of claims of the North over the South. Direct foreign investment and the conversion of debt into equities appear as a possible way to reduce the destabilizing effect of foreign debt but only to the extent that it manages to reduce trade deficits (for example, if foreign companies substitute domestic production of foreign owned firms for exports). This would also require that returns of investment and royalty payments are either reinvested in the South or at least constitute a smaller flow of resources outwards as compared to the service of debt.

Needless to say, this process need not be as crude and devastating as it is described here and reflected in the simulation model. It shall be seen as an extreme result to contrast with optimistic arguments on the benefits of trade.

3 The Model

We consider a two country model (k and k'), with n sectors that produce consumption goods ($1...j...n$) and m firms ($1...i...m$) operating in each sector.[1] The model analyses only consumption sectors. In each economy there is a large nontradables sector along other tradables sectors.[2] Every firm in the tradables sectors may operate in the markets of both countries.

All prices in each country are specified in domestic currency. We assume that gold is the international numeraire so that exchange rates are specified in terms of gold:[3] e_{kt} is the exchange rate of country k with respect to gold, whereas $e_{kk't}$ represents the bilateral exchange rate of the currency of country k with respect to the other country's currency (k'). In every period, the country must obtain foreign currency for international payments to meet obligations with its trading partner either selling goods or borrowing.[4]

Production is assumed to take place under constant returns. Labour and capital are the only inputs in production. Regarding capital, all firms use a unit of physical capital (machines) per unit of output. All machines are

[1] Within each sector, firms produce a homogeneous good.

[2] Nontradability can be seen as the result of very high transport costs for these goods.

[3] It does not mean that international payments are made in gold; it only functions as the numeraire.

[4] We assume that there is no stock of foreign currency reserves.

assumed to have a fixed price in the international numeraire (a machine is worth a unit of gold). Each firm can increase its labour productivity through innovation or imitation of existing techniques: all technological progress is labour saving.[5] R&D expenditure also has a fixed price in gold. The activities in the R&D, capital goods and international transport sectors adapt to the requirements of the consumption sectors and generate a rent equal to the purchases that they satisfy from these sectors.[6]

In each period, micro variables at the firm level are determined first on the basis of the macro data of the previous period, and the results of micro performance determine the macro variables that, in turn, will be the data for firm's decisions in the following period.[7] Behavioural equations in both countries are the same so they will be described in a generic way for country k, with k' being the trading partner. Thus, we will describe the behaviour of firm i of sector j that belongs to country k. Since this firm may sell its product in the home market k or in the foreign market k', when necessary we indicate with a superscript the country in which the firm operates.

3.1 Firms behaviour

3.1.1 Pricing and Investment

Price setting and investment behavior of the firm is assumed to be based on routines rather than on a maximizing behaviour.[8] In each period the firm sets a single price for all markets P_{it} to obtain the funds necessary to expand capacity according to the expected growth of its market.[9] On the one hand, the firm takes into account the rate of capacity expansion that it will be able to finance η_i^F (given expected sales and other funds it may obtain). On the other hand, the firm considers the rate of capacity expansion that it needs η_i^C (to fulfill expected orders). Thus price will be set where $\eta_i^C = \eta_i^F$.

The rate of capacity expansion that the firm expects to be able to finance

[5] Nontradables are not subject to technological progress and represent the largest part of consumption in each country.

[6] These sectors are kept in the shade. One way of looking at them is as if they were integrated and requiring only capital goods for their process of production.

[7] We consider that the period is a quarter. The determination of the macro variables that are used by the firm for the micro decisions is described in section 3.3.

[8] The pricing behaviour of the firm draws on that presented in Metcalfe (1998) and adapts it to an international context.

[9] Production capacity in t is determined by K_{t-1} and investment in t increase capacity in period $t+1$.

equals:

$$\eta_{it}^F = \frac{1}{K_{it-1}} \left(f_i \frac{P_{it} - c_{it}^E}{e_{kt-1}} S_{it}^E \right) \tag{1}$$

where $(P_{it} - c_{it}^E)/e_{kt-1}$ is the margin (in gold) per product that the firm may obtain (c_{it}^E is the expected cost per product), S_t^E are expected total sales and f_i is the propensity to accumulate (proportion of the profit margin that the firm may obtain as investment resources divided by the capital-output ratio).[10] Rearranging, we obtain:

$$\eta_{it}^F = CU_{it-1} f_i (P_{it} - c_{it}^E)/e_{kt-1} \tag{2}$$

where CU_{it-1} is capital utilization in period $t-1$, that we assume to be equal to expected capacity utilization CU_{it}^E.[11] The expected cost per product c_{it}^E is

$$c_{it}^E = W_{kt-1}\lambda_{it} + \frac{e_{kt-1}}{CU_{it}^E}(r + d + r_i^{in} + r_i^{im}) \tag{3}$$

In this equation, c_{it}^E (in the currency of country k) is equal to labour, capital and R&D costs. The labour cost is the wage W_{kt-1} multiplied by labour requirements per unit of output λ_{it}. The second term in equation (3) is the capital cost (in the currency of k) according to expected capacity utilization $CU_{it}^E = CU_{it-1}$, where r is the rate of return, d is the rate of depreciation, r_i^{in} and r_i^{in} are the rates of return of innovation and imitation per unit of capital.[12]

The rate of capacity expansion that the firm needs given expected orders O_{it}^E equals:

$$\eta_{it}^C = \frac{1}{K_{it-1}} \left(O_{it}^E - K_{it-1} \right) \tag{4}$$

Expected orders equal $O_{it}^E = O_{it-1}(1 + g_{it}^{DE})$, where g_{it}^{DE} is expected demand growth for firm i, which equals (recall that firm i belongs to country k):

$$g_{it}^{DE} = \sum_{h=k,k'} \alpha_{it-1}^h \left[g_{jht-1} + \delta_{jh} \left(1 - \frac{e_{hkt-1}(P_{it} + tc_k^h)}{\overline{P}_{jht-1}} \right) \right] \tag{5}$$

[10] It follows from our assumptions that the capital-output is constant and equal to one for all firms in all sectors.

[11] Since each unit of capital produces a unit of product, S_{it}^E is equal to the units of capital that the firm expects to use. Therefore,

$$\frac{S_{it}^E}{K_{it-1}} = CU_{it}^E$$

Observe that capacity utilization affects expected resources to invest.

[12] The wage W_{kt} and the rate of return r are defined at a country level, while r_i^{in} and r_i^{im} are defined at a firm level.

i.e. g_{it}^{DE} is a weighted average of the performance of the sector j (to which the firm belongs) in the two markets in which the firm operates (the home market k and the foreign market k'): $\alpha_{it-1}^{h}$is the weight of market $h = k, k'$ in firm i's sales, g_{jht-1} is the growth of sector j in market h, whereas the last term $\delta_{jh}\left(1 - \frac{e_{hkt-1}(P_{it}+tc_k^h)}{\overline{P}_{jht-1}}\right)$ represents the perception by the firm of the market selection mechanism in that sector in each market. This market selection mechanism depends on the selective pressure δ_{jh} (which we assume to be a parameter) and on the deviations of the price at which firm i sells (P_{it}) with respect to the average price of the market in the previous period ($\overline{P}_{jht-1}$).[13] If the firm is selling to a foreign market, the price must include transport costs $tc_k^{k'}$ between k and k', which are assumed to have a fixed price in gold (Note that $e_{kk} = 1$, and it is assumed that $tc_k^k = 0$).

Thus equation (4) may be rewritten as

$$\eta_{it}^{C} = CM_{it-1}\left\{\sum_{h=k,k'}\alpha_{iht-1}\left[g_{jht-1} + \delta_{jh}\left(1 - \frac{e_{hkt-1}(P_{it}+tc_k^h)}{\overline{P}_{jht-1}}\right)\right] + 1\right\} - 1 \tag{6}$$

where $CM_{it-1} = \frac{O_{it-1}}{K_{it-1}}$ is last period capacity mismatch (which affects desired expansion).

From equations (2) and (6), the firm will set its price according to

$$\begin{aligned} P_{it} \;=\; & \frac{CU_{it-1}f_i c_{it}^{E} + (CM_{it-1}-1)e_{kt-1}}{f_i CU_{it-1} + CM_{it-1}\sum_h \alpha_{iht-1}\delta_{jh}\left(e_{k't-1}/\overline{P}_{jht-1}\right)} \\ & + \frac{CM_{it-1}e_{kt-1}\sum_h \alpha_{iht-1}\left[g_{jht-1} + \delta_{jh}\left(1 - \frac{e_{hkt-1}tc_k^h)}{\overline{P}_{jht-1}}\right)\right]}{f_i CU_{it-1} + CM_{it-1}\sum_h \alpha_{iht-1}\delta_{jh}\left(e_{k't-1}/\overline{P}_{jht-1}\right)} \end{aligned} \tag{7}$$

Firms never set their price below expected costs; however, the margin may be negative if the market outcome does not fulfill expectations.

Once firms have set their prices, and therefore costumers know the average price for a market, each firm obtains a number of orders through the market selection mechanism.

3.1.2 Market selection

The market selection mechanism that disciplines price setting by individual firms is squeezed in a selection equation introduced at a sector´s level. Regarding substitution amongst goods from different sectors, we have assumed

[13] Observe that to set prices the firm considers the average prices of the previous period. But, once all firms set their price, the average that will count for selection is the actual average (selection) price (see below).

that consumption goods have a constant share of income. The mechanism that determines firms' market share and therefore its orders depends crucially on the deviation of the firm's price with respect to the average price in the market. This average price in sector j of market k equals[14]

$$\overline{P}_{jkt} = \sum_{\substack{\forall \iota \in h=k,k' \\ selling\ in\ jk}} \sigma^{jk}_{\iota t-1} e_{kht-1}(P_{\iota t} + tc^h_{kt}) \tag{8}$$

where the weights $\sigma^{jk}_{\iota t-1}$ are the shares of firms ι that sell product j in market k in total sales of that product in that market (measured in quantity).[15]

The market selection mechanism is represented in the following equation, that gives the share that any firm $\iota \in h = k, k'$ (any firm that may belong to country k or k') obtains in the demand of the sector jk:[16]

$$\widetilde{\sigma}^{jk}_{\iota t} = \sigma^{jk}_{\iota t-1} \left[1 + \delta_{jk} \left(1 - \frac{e_{kh}(P_{\iota t} + tc^h_{kt})}{\overline{P}_{jkt}} \right) \right] \tag{9}$$

Observe that for large deviations from average price the share may assume a negative value.[17]

The demand for sector jk equals

$$D_{jkt} = \frac{1}{\overline{P}_{jkt}} \sigma_{jk} A D_{kt-1} \tag{10}$$

i.e. it is the demand, in units of product, that takes place once the firms have set their prices; it depends on the share of sector j, σ_{jk}, in aggregate demand of the country AD_{kt-1}.[18] This sectoral demand will translate into orders for firm i operating in sector j, according to:

[14] A provisional average price in each market, that will be used for selection. It is the weighted sum of the prices (including transport costs) of all the firms (firms ι from countries of origin k or k') that sell in market k.

[15] This tries to capture the idea that once firms set prices in t, their impact depends on their presence in the market at the moment of announcing prices. This is reflected by the share that they achieved in the previous period.

[16] Recall that $e_{kk} = 1$ and $tc^k_k = 0$.

[17] This calculation of $\widetilde{\sigma}_{\iota t}$is the first round in the calculation of real market shares. In this stage we use the selection equation, the prices of the period and the demand of the sector of the market. We have introduced a minimum share value of 10^{-9} of firms in the domestic market and zero in foreign markets to prevent the possibility of negative shares. In a second round this value will be normalized to ensure that all shares add up to one, and will be used to calculate the total sales in the market. Finally, the real "share" will be calculated from market sales.

[18] We assume that the σ_{jk} are constant. Subindex $t-1$ in all macro variables reflects the fact that macro data used in t by firms are determined in period $t-1$.

$$O_{it} = \sum_{h=k,k'} \widetilde{\sigma}_{it}^{jh} D_{jht} \tag{11}$$

i.e. the orders that firm i receives are the sum of the orders that receives from its home country k ($\widetilde{\sigma}_{it}^{jk} D_{jkt}$) and the orders that receive from abroad ($\widetilde{\sigma}_{it}^{jk'} D_{jk't}$).

Production is assumed to take place on the basis of market orders. Firm sales are determined once orders, capacity and labour supply restrictions have been taken into account. Whenever production falls short of orders, firms are assumed to distribute unsatisfied orders evenly among all its markets. Firm sales in each market determine its real share:

$$\sigma_{\iota t}^{jk} = \frac{S_{\iota t}^{jk}}{\sum_{\forall \iota \in h=k,k'} S_{\iota t}^{jk}} \tag{12}$$

Total firm sales also determine its margin and together with external finance the resources available to invest.

3.1.3 Investment of the firm and R&D

Gross investment for firm i equals

$$I_{it} = \frac{f_i (P_{it} - c_{it}) S_{it}}{e_{kt-1}} + dK_{it-1} \tag{13}$$

The first term is the margin multiplied by the propensity to accumulate f_i which includes retained profits and external funding (converted into machine units by dividing it by the price of capital goods), while the second term is depreciation.[19] A firm may have ex-post zero or negative margins if it looses in the competition and fixed costs turn out to be too high, in which case it will not invest.[20] Firms unable to generate positive margins will eventually be driven out of the market. Finally, firms may also invest in foreign subsidiaries whenever shares of exports to a market surpass a certain threshold.

[19] Actual costs c_{it} are calculated as in equation (3) but using CU_{it} instead of CU_{it}^{E}.

[20] It is assumed that firms with losses will cut in this order: first, it will not cover depreciation, and second, it will not cover R&D expenditure. In addition, since firms may find themselves generating a margin but operating with huge excess capacity, it is assumed that margins are not retained for investment when capacity utilization is below a certain limit. Such firms will only cover depreciation.

Innovative and imitative activities are modelled as random process.[21] The probability of obtaining an outcome form R&D innovative and imitative activities is assumed to depend positively on the resources devoted to them. The nature of the outcome is also subject to a random element. Regarding innovation, the outcome λ_{it}^{in} is modelled as a random draw from a normal distribution centered on an exogenously determined mean. This mean is determined by an exogenous science-based rate of technical progress, and constrained to a lower limit determined by nature.[22] The outcome of imitation λ_{it}^{im} is also a random draw from a normal distribution with mean λ_{it-1}. Its lower limit is the labour requirement of the most efficient firm in its own country in the last period. Therefore, R&D spillovers are limited to national boundaries. Since R&D outcomes may not outperform the productivity of the last period, the final λ_{it} will equal:

$$\lambda_{it} = Min(\lambda_{it-1}, \lambda_{it}^{in}, \lambda_{it}^{im}) \tag{14}$$

3.2 Trade and International Payments

Firms' ability to sell in foreign markets depends on their prices being low enough to compete with foreign prices once they include transport costs and are converted according to the prevailing exchange rate. The value of the exports of country k (in gold) are:

$$X_{Gkt} = \frac{1}{e_{kt-1}} \sum_{i \in k} \left(P_{it} + tc_k^{k'} \right) S_{it}^{k'} \tag{15}$$

i.e. X_{Gkt} is the sum of all the sales $S_{it}^{k'}$ made in the foreign country k' by any firm of country k (in value and including transport costs). Similarly, imports of country k (in gold) equal:

[21] A science-based regime is used for innovaation along the lines proposed in Nelson and Winter (1982).

[22] The path followed by the mean of the distribution for each sector is given by

$$\lambda_{jt}^{sc} = \lambda_j^{\lim} + (\lambda_{j0}^{sc} - \lambda_j^{\lim})(1 - g_j^{sc})^{\upsilon t}$$

with $0 < \upsilon < 1$, where $\lambda_j^{\lim}$ is the lower limit determined by nature and g_j^{sc} is the exogenous rate of technical progress. The standard deviation of the distribution is assumed to be a proportion of the mean. Therefore, it becomes smaller as the mean approaches its lower limit.

$$M_{Gkt} = \frac{1}{e_{k't-1}} \sum_{i \in k'} \left(P_{it} + tc^k_{k'} \right) S^k_{it} \tag{16}$$

Aggregate trade flows measured in value could only balance by coincidence. The rule rather than the exception is trade disequilibrium. Leaving aside the buffer mechanism that may result from reserves in foreign currency and the compensating flows of portfolio or direct foreign investment, external current account deficit has to be financed either with debt or selling national assets. The current account (in gold) for country k equals:

$$CA_{Gkt} = X_{Gkt} - M_{Gkt} + R_{Gkt} \tag{17}$$

where R_{Gkt} are net rents (in gold). These rents are the result of applying an international fixed interest rate on net foreign assets F_{Gk}. The latter are the result of positive current account balances which translate into lending to trading partners with deficit.

The country that has negative assets has to pay an interest even if it has to borrow to do so. The repayment of the principal is not scheduled. The country pays back when it generates trade surpluses large enough to cover interests and repay debt.

We assume that, in response to current account deficit, the exchange rate will adjust towards PPP (i.e. the government will devaluate gradually to achieve parity of the average price of its tradables sector with the average price of tradables of the rest of the world). Thus the exchange rate of country k currency with respect to gold will be:

$$e_{kt} = \frac{e_{kt-1}}{P^{Tr}_{k't}} \left(\frac{\sum_{i \in Tr} P_{it} S_{it}}{\sum_{i \in Tr} P_{it-1} S_{it}} \right) \tag{18}$$

where Tr represents the tradables sectors and $P^{Tr}_{k't}$ is the price index of tradables of the rest of the world k'. The exchange rate adjustment is set in motion when borrowing from abroad surpasses a limit.[23]

3.3 The Economy

At the end of the period, aggregate variables that will be used in the firm's decisions next period are determined. The wages in each country will partially adjust to the increase in the price index and also to changes in productivity.

$$W_{kt} = W_{kt-1} + \Omega_1 g^P_{kt} + \Omega_2 g^{\overline{\lambda}}_{kt} \tag{19}$$

[23] This borrowing limit is set as a proportion of borrowing relative to GNP.

where $0 \leq \Omega \leq 1$, g_{kt}^{P} is the rate of inflation and $g_{kt}^{\overline{\lambda}}$ is the productivity growth.[24] We assume that nominal wages are rigid downwards, that there is a minimum real wage of subsistence in terms of quantities of each product w_{jkt}^{subs} . These quantities determine a minimum wage in nominal terms (below which no worker can work):

$$W_{kt}^{subs} = \sum_{j \in k} \overline{P}_j w_{jkt}^{subs} \tag{20}$$

Aggregate demand for consumption goods plays a key role driving and giving stability to the pattern of growth in the economy. Aggregate demand expansion for period $t+1$ is assumed to take place every quarter on the basis of money income generated in period t (from firm sales and investment). This expansion together with investment financed with external sources are the only autonomous sources of growth for the economy, while trade surplus and net rents from abroad are a beggar-thy-neighbour sources of growth for an economy.[25] The aggregate demand for $t+1$ (in value) is calculated in t as

$$AD_{kt} = \left(Y_t + Y_{t-1}^{U}\right)(1 + \rho_{kt}) \tag{21}$$

where Y_t is the income generated in that period, Y_t^U is unspent income generated in the previous period and ρ_{kt} is an exogenous rate of aggregate demand expansion. Therefore, the path of economic growth is "semi-endogenous": the level of activity is determined every period on the basis of the competitive process in the various markets, but there is also an exogenous source of aggregate demand expansion driving the process of economic growth.

[24] The rate of inflation is calculated on the basis of a consumer price index updated every quarter (no weigths are needed since we have assumed constant proportions in consumption):

$$g_{kt}^{P} = \frac{\sum_{j \in k} \overline{P}_{jt} S_{jt-1}}{\sum_{j \in k} \overline{P}_{jt-1} S_{jt-1}} - 1$$

While productivity growth is an average of sectoral productivity increases weighted by the value of the sectoral products:

$$g_{kt}^{\overline{\lambda}} = \frac{\sum_{j \in k} (\overline{P}_{jt-1} S_{jt-1}) \left[(\overline{\lambda}_{jt-1} / \overline{\lambda}_{jt}) - 1 \right]}{\sum_{j \in k} \overline{P}_{jt-1} S_{jt-1}}$$

[25] I.e. they substract aggregate demand from the country that makes the imports or sends the rents.

4 Simulation exercise and results

As mentioned in the previous section, the behavioural equations are identical in the two countries and differences are introduced through initial values and parameters in the simulation exercise.[26] The simulation has been done for two low-dimension economies consisting each one of three sectors: a large nontradables sector that uses only labour and is not subject to technological change, and two sectors of tradables with different initial labour intensity. There are only two firms in each sector, and they are assumed to be identical at the beginning of the simulation. In this simulation exercise we have kept asymmetries between countries to a minimum in order to highlight the impact of productivity gaps as a source of trade and uneven development. Both countries start from a situation of labour shortage and excess capacity. Population is assumed to grow at a decreasing rate and the rate of exogenous increments to aggregate consumption demand is a linear function of that rate.[27] In these and other respects the countries are assumed to be identical with the exception of their technological performance. The two factors that distinguish North from South are: a) A higher rate of science-based technological progress in the North in both consumer sectors: both countries start with the same average labour productivity in the tradables sectors and at the end of the simulation average productivity in tradables is 52% higher in the North than in the South; b) Relative rates of technological progress between sectors follow an opposite pattern in the two countries: while the North progresses faster in the sector characterized by lower labour intensity, the South has a higher rate in the sector that uses more labour per unit of output. By the end of the simulation the ratio of average labour productivity between the labour intensive sector and the less labour intensive sector are 0.34 in the North and 0.57 in the South. Such a difference induces trade specialization according to comparative advantage in which the South becomes an exporter of labour intensive goods.[28]

At the beginning of the simulation high transport costs and absence of innovation determine a period of autarky. As it would be expected, the autarkic evolution of the two countries is identical in all respects at the beginning of the simulation, as the early period of the evolution of aggregate consump-

[26] Simulations have been made using LSD software (Valente, 1999; Valente and Andersen, 2000).

[27] In the simulation, population for each period both countries was calculated as: $Pop_t = Pop_0 \left[1 + (0.0095t)^{0.95}\right]$, where $Pop_0 = 1000$.

[28] Complete specialization is precluded in the model by guaranteeing a minimum share to the firms in their home market to keep alive the pressure on foreign competition.

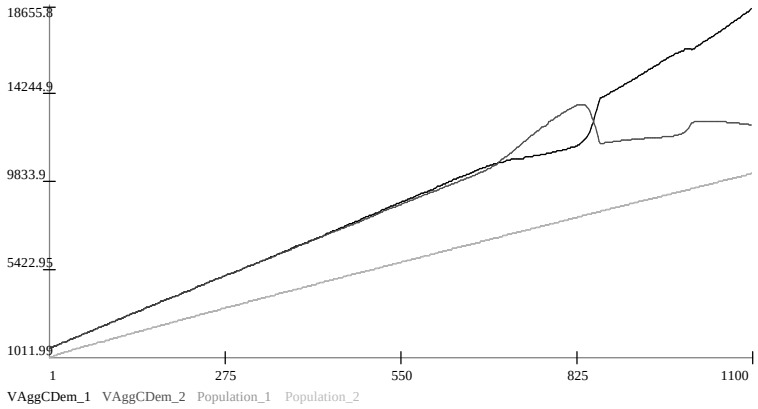

Figure 1: Aggregate consumption demand (in domestic currencies) and population.

tion demand shows (figure 1).[29] Also, at the micro level, the behaviour of sectors and firms within each country is a replica of that of its future trading partner until productivity increases are introduced. In period 300 of the simulation, innovation and imitation start to produce results. As mentioned above imitation is restricted to firms within the same country (there are no international spillovers).

Based on these assumptions, the results of the simulation exercise are the following:

1. Once innovation starts in both countries, the competitive struggle inside the two countries is the mayor source of macroeconomic instability. As it can be seen in figure 2, at the micro level, productivity advantages translate in changes in market shares within the countries, and in some sectors it leads to the domination of one firm in the domestic market. Losses of market shares increase fixed costs for some firms and, despite innovation, they may translate into higher prices.

2. Low-price products from abroad find a gap in the domestic market. The North is the first to have an advantage in international trade due to the higher speed at which it achieves cost reductions (see figure 3).

3. As trade starts to take place amongst the two countries, trade and current account imbalances are the rule, since trade equilibrium could only

[29] In the figures, variables are followed by up to four numbers. These numbers denote, in that order: country, sector, firm and market in which the firm operates. Regarding the country (and the market), number one makes reference to the North and number two to the South. Thus, all variables followed by an initial 1 correspond to the North while those followed by a 2 correspond to the South.

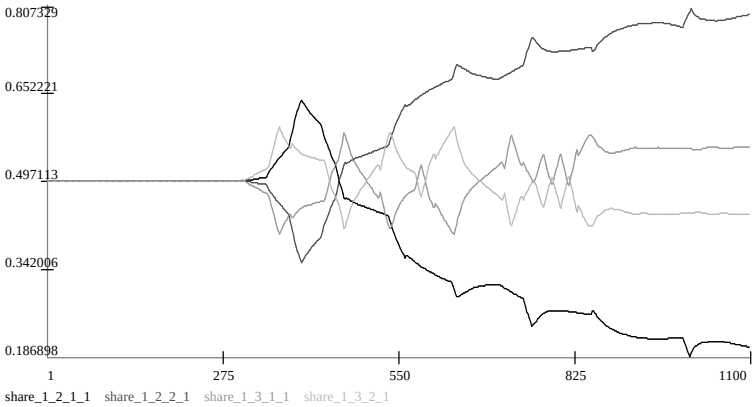

Figure 2: Northern changes in domestic market shares

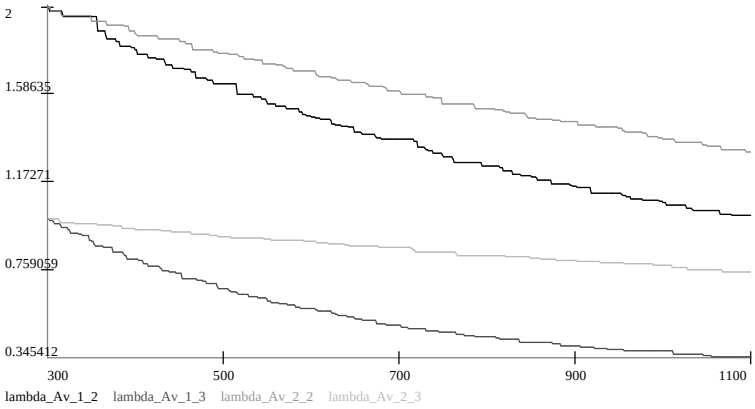

Figure 3: Reduction in labour requirements in both countries.

occur by coincidence (figure 4).

4. The initial trade imbalances are financed with international borrowing. But when external disequilibrium reaches a critical point countries adjust their exchange rates in order to revert their balance of payments deficits. Although countries exports take place according to productivity determined comparative advantage, one-way trade and trade balance reversals dominate the scene, as a result of exchange rate adjustments. We observe alternating periods of trade domination by the North and by the South, as shown in figure 4. When the North dominates, it exports low labour intensity goods, while in periods of Southern domination, the South exports the labour intensive goods.

5. Both countries devalue in periods of negative external disequilibrium

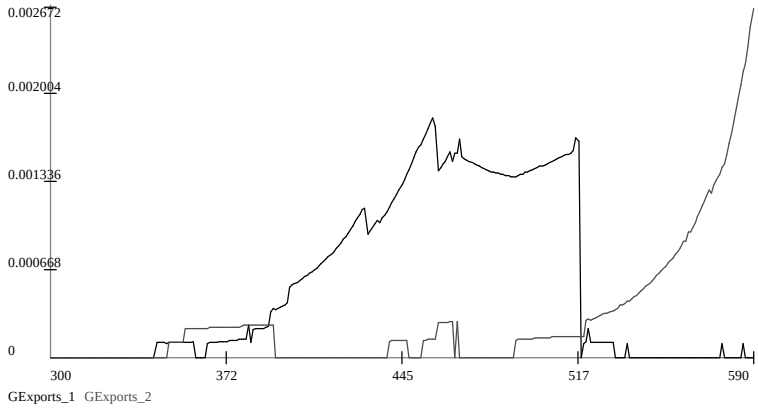

Figure 4: Emergence of trade flows (periods 300 to 590).

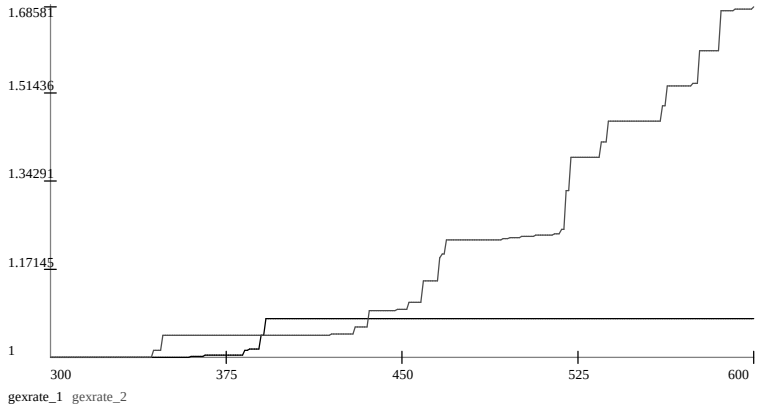

Figure 5: Evolution of exchange rates.

to restore balance. However, devaluations are greater in the South in order to compensate the productivity advantage of the North (figure 5).

6. As the simulation shows, the working of the model tends to give high weight to the disequilibrating side of international trade and payments. Firstly, trade deficits, even if they are small, have a negative influence on the economic activity of the countries that incur in such deficits.[30] Accumulated debt due to trade deficits and to the need to borrow in order to repay the service of the debt is another factor that adds up to the current account disequilibrium. It generates negative net rents from abroad, that also have a negative effect in growth. These mechanisms drain the resources that

[30]In a simulation run without innovation and no trade the countries grow steadily at the rate fixed exogenously in the aggregate consumption demand equation.

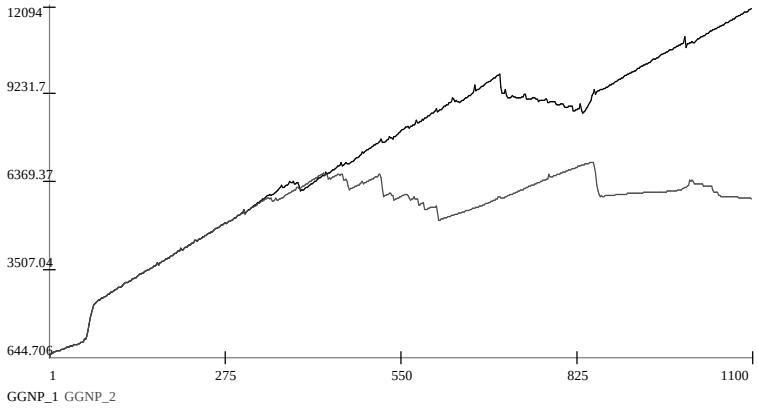

Figure 6: Widening gap in GNP (in gold).

feed domestic demand for consumption goods in the beggar-thy-neighbour fashion described in section 2. Finally, devaluation as a mechanism to gain competitiveness is limited. It also increases costs and prices measured in domestic currency and in this way it contributes to reduce sales, production and therefore, aggregate demand for subsequent periods.

7. The gap in the value of GNP of the two countries (measured in gold) widens in the course of this process (see figure 6). The simulation is reported until the period in which the GNP of the South measured in gold falls below the level required to give a subsistence wage to its population.[31] An extreme devaluation of domestic currency is a major destabilizing factor that adds to the contractionary effects of a current account disequilibrium and contributes to precipitate this situation. Devaluation combined with economic contraction no longer translates into competitiveness but instead raises the cost of capital, which translates into price increases and helps to precipitate aggregate demand down. Not even a trade control imposed when the economy was reaching a critical situation is able to stop disaster in the South.

At this point one might speculate on possible ways out for the South. These mechanisms could be introduced in the model (as the unsuccessful trade control of the simulation exercise) to explore their impact. One is direct foreign investment: replacing debt with direct investment and imports with domestic production by foreign owned firms may reduce debt. However, the outflow of royalty payments would have to be taken into account and similar considerations apply to the conversion of debt into equities of Southern firms. Finally, more stable patterns of autonomous financial flows

[31] If taken beyond this point, the South GNP becomes zero and passes to negative values (no production and only negative net rents) and the results are no longer meaningful.

could be introduced in the model as a possible source of stability. But an adequate treatment of this flows would require an extension of the model including behavioural equations for the financial sector, the determination of interest rates and its interactions with exchange rates. These questions are beyond the scope of this paper.

In the simulation exercise, Northern domination over the South takes the form of positive net foreign assets . Another form of control over Southern real assets is direct foreign investment. In other simulation exercises in which exogenous rates of sectoral demand are imposed together with productivity asymmetries, the control of Southern markets by more productive foreign owned firms is an obvious and immediate result. However in the scenario of this simulation, trade imbalances and fluctuations in economy activity dominate and the crisis in the Southern economy occurs before the process of direct foreign investment can take off.

5 Conclusions

The model presented in this paper concentrates in the analysis of trade in consumption goods which are subject to labour saving technological progress. We have used several assumptions that bring into the model some of the mechanisms described in Section 2, while avoiding theoretical problems that the model does not attempt to tackle. An important theoretical shortcut has been to keep the production of capital, transport and R&D activities in the shade. We sidestep their analysis treating them as integrated, totally unconstrained and responding entirely to the demands of the consumption sectors. We have also introduced an international numeraire labeled "gold" and, since all machines in spite of being specific to each sector are worth a unit of gold, it is in fact machines which constitutes the international numeraire. In this way the variation in the conditions of production of this numeraire has been assumed away.[32] Needless to say, this treatment of capital is not entirely satisfactory, since it avoids all the questions related to the value of capital and the implications of sectors interdependence. Such assumptions are justified as an admittedly unrealistic and stylized way to capture two of the mechanisms that are behind the difficulties faced by firms from underdeveloped countries competing in the international economy. First, production processes tend to depend heavily on the import of foreign capital goods; thus,

[32] One type of machine could be chosen as numeraire and a fixed price structure of machines could be assumed. By the same token diferences in capital output ratios could be introduced between sectors. However, this would introduce unnecessary complications that would add nothing to the analysis.

domestic costs increase in domestic currency when the country attempts to gain competitiveness through devaluation. Second, both as a result of international capital mobility and to the stronger position of capital in the distributive struggle, devaluations tend to shift distribution in favour of the latter: although after a devaluation both wage and country assets depreciate in international terms the value of the latter tends to recover faster than the purchasing power of the wage bill. By fixing in gold the price of capital, R&D and transport costs, the joint effect of these two mechanisms is brought together. As a result of these assumptions, this aspect of dependence of imports on capital goods entered in the model as a symmetric situation for both countries.[33] By ignoring the negative effect on the trade balance of more expensive imports of capital goods, we are leaving aside an additional burden on the South when it uses devaluation as a way to gain competitiveness. If trade in capital goods and the asymmetric situation of North and South with respect to the import of capital goods were introduced, the argument on the limits of devaluation as a way to correct external disequilibrium would be reinforced. The analysis of trade in capital goods would be at the top of the agenda in a model that fully integrates the capital goods sector and sectoral interdependence.

Another aspect worth mentioning is the consumer side of the market. We have assumed constant shares in consumption expenditure for the tradable goods. This symmetric treatment of tradables leaves aside the advantages of specialization that may arise from the demand side related to changes in demand associated with changes in per-capita income. The tendency of countries lagging behind to lock in patterns of specialization which are unfavourable from the perspective of the tendencies in the demand of the international market is also an important aspect of uneven development. This is a question that can be better analyzed in a model with product innovation.

The simulation exercise reported in the paper emphasized the destabilizing effects of international trade and international borrowing, to the extent that it can threaten the viability of the southern economy. In the scenario of this simulation, differences in income are captured by the diverging path of the countries GNP measured in the international numeraire. With respect to domination of the North over the Southern economy, it takes the form of export penetration and positive net foreign assets which, as any debt, in the end constitute claims over Southern real assets. Another form of control, that does not operate in the scenario reported in the model, is direct foreign investment, in which more efficient foreign owned firms became dominant in

[33] In the model the burden of adjustment is always placed on the country with deficit; therefore, currencies can only devalue in terms of gold.

southern markets.

As it was mentioned in the final comments of the previous section the results obtained in the simulation exercise are far from being conclusive. The scenario built there was one in which countries were prone to be destabilized by external sector imbalances and exchange rate adjustments. A different pattern could be obtained introducing conditions and mechanisms that make countries more resilient to their effects. As it was pointed out in section 1, the possibility of implementing this diversity of scenarios and associated differences in results shall be seen as a strength rather than a weakness of simulation models as a tool of analysis. An obvious extension to the simulation exercise reported in this paper is to explore the extent to which different economic conditions such as dynamism of aggregate demand, weight of the external sector or autonomous flows of foreign investment may help to counteract the contractionary tendencies of the Southern economy. Along the same lines the model shall be extended to simulate different institutional settings that determine the mechanisms of exchange rate adjustment, the regulation of trade and financial flows, and technological spillovers in order to examine the extent to which they contribute to modify the patterns of development of the economies.

Finally, as we mentioned in section 3, in the model growth is semi-endogenous. The competitive struggle explains fluctuations in economic activity but there is also an exogenous demand pull feeding the process of growth. A topic for further research is to introduce entrepreneurship and innovation in a truly endogenously driven growth.

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