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Structural change, an open economy and employment: A structural change and economic dynamics approach

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Abstract:

The main objective of this paper is to analyse the effects of international trade on employment, focusing particularly on the case where domestic prices are higher than foreign prices, using Pasinetti's (1981 and 1993) framework as the basic structure of analysis. It is shown that technological progress affects employment levels through the Kaldor-Verdoorn law by endogenizing productivity growth when national prices are competitive. We conclude that high imports negatively affect employment levels, supporting heterodox views regarding trade openness.

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The main objective of this paper is to propose an extension of the theory of structural change and economic dynamics (SCED) based on Pasinetti (1981, 1993) and Araujo (2013), where different consumption profiles are considered to support debates about the impacts of technological development on the economy under international trade. We also discuss the effects of international trade on employment conditions, especially on international competitiveness. To develop our new approach, we consider Araujo's model to assess the case where national prices are higher than global prices. Thus, we intend to show the relevance of the topic addressed in this paper to the present SCED literature as well as to the Kaleckian income distribution approach. Using our model, full employment of factors and perfectly competitive markets are considered to be special cases.

SCED is a theory that simultaneously handles the demand and supply sides of the economy. This approach assumes a multisectoral setting incorporating the evolution of

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consumption, population and productivity (Pasinetti, 1987). Pasinetti's dynamic model deals with the income elasticity for different goods, which changes over time as per capita income increases. These effects cause variations in the production structure and technological change, allowing consumers the most considerable range of goods. These results were identified by Pasinetti (1981, 1993) as well as by Araújo and Teixeira (2016). The latter show the inconsistency of the link between an increase in income and consumption levels, which has been justified by Engel's law.[1]

In economic theory in general, and macroeconomics in particular, there has been substantive disagreement on the relationship between technological change and unemployment (especially in the short and medium run). Such questions have been debated for a long time. Ricardo ([1821] 2001) thought innovation was potentially harmful for employment but a necessary condition for a nation's development. Marx ([1856-7] 1993) saw capitalism as characterized by an intrinsic tendency to generate technological unemployment, subject to countertrends. For Wicksell ([1901] 1977), technological development would bring an optimal balance – with product maximization and wage increases. All of them contributed to consolidating such debates in the economic literature, but the relationship between technological change and unemployment has not yet been very well explained. Hence, our primary goal is to derive a theoretical extension to link both phenomena properly.

Some authors deal with such considerations with a focus on the labour force, arguing that technological innovation should be positively related to employment (see Laffargue, 1997). From the heterodox perspective, according to Barletta and Yoguel (2017), the structural change literature is divided into four groups, two of which specifically deal with the relationship between technology and employment. The first group started with Lewis and Kuznets's works on reallocation of the workforce to higher-productivity sectors (Prebisch, 1949; Singer, 1950 and Hirschman, 1958). The second group argues that structural change is the only way that uneven economies can become developed economies (Schumpeter, 1961; Nelson and Winter, 1982 and others). The third group shows that structural change is a result of the evolution between demand and supply processes (Kaldor, 1957; Saviotti and Pyka, 2004; Porcile, 2021, and others). Finally, the fourth group is the one represented by Pasinetti, who builds on the work of the third group by disaggregating the economy into sectors but considers the supply and demand conditions necessary to yield full employment of factors. These assumptions are relaxed by considering the Kaleckian perspective and introducing market imperfections and the differences between normal and usual capacity utilization.

The last group also builds on the work of the third and first groups by considering a pure labour economy. This stream of literature is the one that theoretically supports our work and is defended by Pasinetti, Salvadori, Teixeira, Araujo, Lima, Dutt and others. Therefore, even for neoclassical authors, these aspect – presented by Laffargue, 1997 – are the foundation of the consensus that the core of innovation is workers' substitution by technology, since one machine may produce on a large scale while only one or two highly specialized workers are employed, thus "stealing" jobs, which impacts the income distribution when unemployment increases among the less specialized workforce, as shown by Korinek and Stiglitz (2017). Like Acemoglu and Restrepo (2018), other orthodox figures recognize that technological innovation

[1] In brief, Engel's law was identified from the empirical regularity that as personal income rises, the consumption of essential goods, such as food, decreases proportionally. This dynamic holds for other goods. That is, as real income rises, the share of goods in consumption also varies, the introduction of new products changes consumption patterns, and every commodity or service has a saturation point.

can increase labour productivity but reduce wages, demand for workers, and employment. However, these authors explore the economy's supply side without properly considering labour market theory in their models.

Regarding the post-Keynesian view, economists such as Skott (2019), have examined the supply side under autonomous demand, affecting Harrodian instability. Extensions of Rehn-Meinder's model developed by Erixon (2018) and Magacho and McCombie (2020) also analyse the impact of the supply side with different degrees of increasing returns and kinds of income elasticities to exports and imports on the demand side and other issues that affect the economic structure and income distribution. Therefore, debates related to this field generate questions about the social and individual consequences of innovation. Common sense suggests that innovation generates benefits, at least, to manufacturing.

However, there is no consensus about the social benefits, especially the consequences of falling unemployment. Tomkiewicz (2017) shows that greater investment in capital and technological innovation affects corporations' profit but not wages or employment levels. Pariboni and Tridico (2019) have shown that the labour share declines with increased innovation, and to prove their points, they analyse a sample of OECD countries by identifying financialization driven by structural change. Hartwig (2015) developed a traditional Kaleckian model considering SCED to analyse the possible trajectory of employment in OECD economies over the 1970-2010 period.

Unlike the research presented above, we verify the effects of technological progress on both the supply and demand sides of employment based on a theoretical setup in which national prices are higher than international prices.

This paper is divided into five sections. The first is this introduction, which summarizes the debate on structural change and employment between orthodox and heterodox economists. The second offers a review of the SCED approach and its extensions, giving special attention to the Araujo (2013) extension. The third section reinterprets Pasinetti's extension for an open economy, focusing on the case in which national prices are higher than global prices, which has not been analysed by the previous literature. The fourth section considers endogenous productivity growth, which raises new interpretations of our framework, and the final section contains the concluding remarks.

1. A review of the SCED model considering an open economy

SCED is a theory that treats the demand and supply sides simultaneously while considering multiple sectors in the economy, including – among other things – consumption trends. These dynamics occur due to distinct income elasticities between goods and services, whose consumption patterns change over time, driven by the per capita income increase. This effect leads to changes in the production structure, and technological progress increases the variety of goods available to consumers. These results were presented by Pasinetti (1981, 1993) as well as Araújo and Teixeira (2016) and are explained by Engels's law, which demonstrates that the level of consumption and the variety of goods and services are not constant as income increases.

Pasinetti considers exogenous technological progress in a closed economy, where such progress increases real per capita income. It causes an uneven higher consumption of goods and services according to Engel's law. For the following analyses, we consider a model based

on vertically integrated sectors[2] on an $n-1$ scale where only labour is used as input to produce output. In this case, the focus is on the final goods and not on the industries. As Pasinetti (1993, p. 15) stated, it is a "minimal theoretical scheme that allows the representation of almost all the basic characteristics of the structural dynamics of a production economic system". Therefore, the effective demand able to generate the necessary output that guarantees full employment, according to Pasinetti, respects the following condition:

$$\sum_{i=1}^{n-1} a_{i,n}(t)a_{n,i}(t) = 1 \quad (1)$$

where $a_{i,n}$ expresses per capita demand for good i and $a_{n,i}$ is the technical coefficient of production of the i^{th} good. n represents the total population and, in this case, the total working population. It is necessary to consider two goals to define equation (1). The first is full employment when this equality is achieved. In other words, each term *i* in equation (1) states the proportion of total labour applied in the production of the i^{th} sector. The second goal denotes the demand paths that can guarantee the equilibrium position in all periods, including at time zero. Therefore, equation (1) states the necessary but insufficient requirements to ensure macroeconomic equilibrium (Araújo and Teixeira, 2016).

Furthermore, as the coefficients of equation (1) may vary over time, we assume two exponential functions, (2) and (3), for time-varying per capita demand and a technical coefficient for simplicity. Thus:

$$a_{in}(t) = a_{i,n}(0)exp\ (r_i t) \quad (2)$$

$$a_{ni}(t) = a_{n,i}(0)exp\ (-\rho_i t) \quad (3)$$

Note that the rates of growth can vary between sectors, with r_i representing the annual rate of growth in consumption patterns. ρ_i indicates the changes in labour productivities, meaning a decrease in the labour coefficients over time if $\rho_i > 0$ – which is expected in almost all sectors and results from learning. After some mathematical manipulations of equations (1), (2) and (3), proper effective demand is determined, following the approach of Pasinetti:

$$\sum_{i=1}^{n-1} a_{i,n}(0)a_{n,i}(0)exp\ (r_i-\rho_i)t = 1 \quad (4)$$

In this case, we consider the sum presented by equation (4) to be less than one; then, there is unemployment in the economy[3] given that one is considered full employment, as found by Pasinetti. In equation (4), if $r_i = \rho_i$, increasing demand in a sector is compensated by productivity gains, maintaining the level of employment in the sector. Moreover, if $r_i = \rho_i$ for each sector *i* and the equation (1) holds, the economic dynamic system remains in equilibrium at full employment, and the sectors preserve their proportions over time. However, this assumption is artificial and unrealistic.

Evolution in labour productivity commonly leads to an increase in real income. However, the relation between the real income increase and demand is not straightforward, mostly because of the regularities described by Engel's law (Pasinetti, 1993). Therefore, the economic dynamics of technical progress raise some questions about the labour market and consequences on employment. Furthermore, this approach considers possible imbalances in goods as well as labour markets (Antunes and Araujo, 2020).

[2] This consideration of vertically integrated sectors permits us to explore the consequences over time of the evolution of output, productivity and employment Hagemann (2012). This framework also allows a higher degree of disaggregation to a neo-Kaleckian model as in Araújo and Teixeira (2016).

[3] See Shapiro (1984) and Pasinetti (1981).

These issues are considered in the Kaleckian framework, where capital (or labour) subtilization is considered, as in Hartwig (2015) and Araújo and Teixeira (2016). On this matter, Araujo (2013) and Araujo and Trigg (2015) incorporated some market imperfections into the system by analysing technology changes impacting demand and productivity. The main version of SCED addresses demand-led growth, which is an important issue for understanding the role of workers. Araujo (2013) developed an extension of the original Pasinetti (1981) model, analysing the consequences of an open economy for sectoral economic dynamics.

The discussion of employment conditions in a dual economy was started by Lewis (1954) when he analysed the effect of an unlimited labour supply on economic development, starting the first stream of literature presented by Barletta and Yoguel (2017). His conclusion was that labour productivity can be zero or even negative in a country where the subsistence sector is overpopulated. In the case of an open economy, Lewis shows that exports reduce capital formation and reduce wages to subsistence levels, hindering economic development. The SCED approach adopted this perspective to explain employment flows, especially with respect to international trade.

However, how can this special case be identified? How can we manage this kind of situation? Buchanan et al. (2013) have shown that such an economy would create combinations of different employment types, legally differentiated according to each country: for example, full-/part-time employment or temporary/permanent employment. The authors concluded that labour productivity is higher than the real wage in developed economies but that this difference can be lower than in other economies. They led us to question the possibility of having an overpopulated economy or an excess level of employment.

Based on the theory presented above, Araujo (2013) developed an extension, intending to understand the dynamics of an open economy in a country with uneven development. He showed the impact of employment in dynamic growth and income distribution situations. However, he did not present the case in which national prices are higher than external prices, which modifies the labour market interpretation and dynamic price behaviour under this approach. Our objective in the next section is to analyse this case.

2. A reinterpretation of Pasinetti's extension to an open economy

This analysis attempts to extend Pasinetti's pure labour model (Pasinetti, 1993) to the case of an open economy, expanding some points originally raised by Araujo (2013) and Araujo and Teixeira (2003). The macroeconomic equilibrium condition presented by the first author is represented by equation (1), and after we apply some mathematical manipulations, the equation shows that the working population (X_n) is not equal to the total population. In this vein, equation (1) should be restated as:

$$\frac{1}{\mu(t)\nu(t)}\sum_{i=1}^{n-1} a_{i,n}(t)a_{n,i}(t) = 1 \qquad (1')$$

where $0 < \mu(t) < 1$ is the proportion of the current economic population to the total population and $0 < \nu(t) < 1$ indicates the total working time relative to total available hours. Therefore, equation (1') "expresses the size of full employment" (Pasinetti, 1993, p. 50).

Pasinetti (1993) used this analysis to verify the effects of an increase in labour productivity. Using the time transformation applied by Pasinetti (1981 and 1993), it is possible

to evaluate employment in sector $i = 1,2, \dots, n-1$ in relation to a closed economy and exogenous productivity growth as follows:

$$E_i(t) = a_{n,i}(t)X_i(t) = a_{n,i}(t-\theta)a_{i,n}(t-\theta)N(t-\theta) = a_{n,i}(0)a_{i,n}(0)N(0)e^{(g+r_i-\rho_i)\theta} \quad (5)$$

where X_i is total domestic production, N is the population, and g is the population growth rate. This represents the so-called structural dynamics of employment (Pasinetti, 1993, p. 51) because it shows the basic time-varying causes of the composition of employment in the economy. The time structure reproducing Pasinetti's time transformation (Pasinetti, 1981) represents a division of time of finite stretches where r_i remains constant for each commodity. This setup permits variations over time in the rate of change of per capita demand and technical progress. For simplicity, the time indicator is suppressed when no misunderstanding is possible.

For our purposes, an international trade framework enhances labour market analyses. Pasinetti did not formalize the implications of foreign exchange,[4] which was done by Araujo and Teixeira (2003). These authors derived the version of equation (1') for the case of an open economy, described, with some notation modifications, as:

$$\frac{1}{\mu\nu}\sum_{i=1}^{n-1}(a_{i,n} + \xi a_{i,m})a_{n,i} = 1 \quad (6)$$

where $\xi = X_m/X_n$ is an equalization factor between the internal and foreign populations. Appendix A.1 explains this in detail. Furthermore, the subscript m represents another country (or the rest of the world). $a_{i,n}$ is the per capita demand coefficient of good i among the domestic population, and $a_{i,m}$ is the per capita demand coefficient of good i among the foreign population, both produced in the same country, say, U. $a_{n,i}$ is the technical coefficient of production in terms of labour. The extra term ($\xi a_{i,m}$) in equation (6) denotes other instruments to dynamically maintain the macroeconomic equilibrium. However, it refers only to the full employment condition, and it is incomplete, as we see below.

Additionally, Araujo and Teixeira (2003) established that the equilibrium of the balance of payments requires a more restrictive condition:

$$\frac{1}{\mu(t)\nu(t)}\sum_{i=1}^{n-1}(\xi a_{i,m} - a_{i^*,n})a_{n,i} = 0 \quad (7)$$

Equation (7) shows that the imports, represented by the per capita demand for good i produced abroad – hereafter i^* – among nationals ($a_{i^*,n}$) and exports ($a_{i,m}$), weighted by the labour coefficient and measured in labour quantities, must be equal.

Another path to the demand growth rate for an open economy depends on relative prices.[5] We depart from Araújo (2013) but add the case that considers the impacts on internal production when the price ($p_{i^*}^A$) of some good i produced in, say, country A (here, an advanced economy) is smaller than the price of the good in country U (p_i^U) (here, an underdeveloped economy), i.e., when $p_i^U > ep_{i^*}^A$. In this case, e is the nominal exchange rate between the currency of country U and the currency of country A.

To handle these questions, we consider that domestic production of product i (X_i^U) to supply (subscript s) the internal ($X_{s,i}^U$) and foreign markets ($X_{s,i}^A$) is characterized by:

[4] In fact, Pasinetti (1993, p. 161) dealt with the potential benefits to productivity from international trade when employment is protected, which is not the case here.

[5] The relevance of the use of the comparison in terms of labour can be seen in Araujo and Teixeira (2003).

$$X_i^U = X_{s,i}^U + X_{s,i}^A \tag{8}$$

Internal demand (D_i^U) can be given by:

$$D_i^U = X_{d,i}^U + X_{d,i^*}^A \tag{9}$$

where $X_{d,i}^U$ is internal demand (d) for national product i and X_{d,i^*}^A indicates national demand for foreign product i. Both equations (8) and (9) are simply identity accounts. Dividing both sides of [9] by the total population of country U and using the definitions of per capita demand, we have:

$$a_{i,n}^U = \frac{D_i^U}{X_n} = \frac{X_{d,i}^U}{X_n} + \frac{X_{d,i^*}^A}{X_n} = \tilde{a}_{i,n}^U + a_{i^*,n}^U \tag{10}$$

The upper superscript represents the country under analysis. $a_{i,n}^U$ stands for total internal per capita demand, $\tilde{a}_{i,n}^U$ is per capita demand for domestic products and $a_{i^*,n}^U$ denotes per capita demand for external products, all for good i. Now, the entrepreneurs of country U under analysis are subject to external competition. We can rewrite equation (10), isolating the total demand for domestic products or services, as:

$$X_{d,i}^U = (a_{i,n}^U - a_{i^*,n}^U)\, X_n \tag{10'}$$

where we obtain the result of demand for good i given the national demand for imports. Here, at least part of the internal demand may be supplied by firms in country A. Price competitiveness and product quality are elements that drive this choice.

Considering the equalization between domestic demand for national products and national production for the internal market, we have $X_{d,i}^U = X_{s,i}^U$. Therefore, we substitute equation (10') into equation (8) and divide both sides by the population of country U, and after some algebraic manipulations, we have:

$$X_{\mathrm{i}}^{\mathrm{U}} = (a_{i,n}^U - a_{i^*,n}^U + \xi a_{i,m}^U)\, \mathrm{X_n} \tag{11}$$

where ξ is, again, the coefficient of proportionality between both populations. Therefore, the presence of good i in a tradeable sector's national production depends on it being cheap enough to face international competition, and it was not considered by equation (6). In addition, we should observe that when $p_i^U \leq ep_{i^*}^A$, $a_{i^*,n}^U = 0$, and when $p_i^U \geq ep_{i^*}^A$, $a_{i,m}^U = 0$, representing the nonexistence of a comparative price advantage in sector i in the short run. In this case, there would be no international trade in that sector, which is important for the model's dynamics.

Next, for the dynamic analysis, we adopt foreign per capita demand as a version (Araujo, 2013; Araujo and Lima, 2007) of the standard export demand function based on Thirlwall (1979) and considering comparative price advantages:

$$a_{i,m}^U = \left(\frac{p_i^U}{ep_i^A}\right)^{\eta_i} y_A^{\beta_i} X_m^{\beta_i - 1}, \qquad if\ p_i^U < ep_{i^*}^A \tag{12}$$

where y_A is the per capita income of country A. $\eta_i < 0$ is the price elasticity of external demand. $\beta_i > 0$ is the income elasticity of external demand. In addition, internal per capita demand for imported goods and services is given by:

$$a_{i^*,n}^U = \left(\frac{ep_i^A}{p_i^U}\right)^{\psi_i} y_U^{\phi_i} X_n^{\phi_i - 1}, \qquad if\ p_i^U > ep_{i^*}^A \tag{13}$$

where y_U is the per capita income of country U. $\psi_i < 0$ is the price elasticity of internal demand. $\phi_i > 0$ is the income elasticity of internal demand for foreign goods. From both equations (12) and (13), we should note that international trade is a function of relative prices and per capita income. These characteristics are determinant in the analysis of the evolution of consumption.

Then, using the same conventions as in Araujo (2013), where dots indicate variation in time, we have $\left(\frac{\dot{p}_i^U}{p_i^U}\right) = \sigma_i^U$, $\left(\frac{\dot{p}_{i^*}^A}{p_{i^*}^A}\right) = \sigma_{i^*}^A$, the price variation of good i produced in the countries U and A, respectively; $\left(\frac{\dot{e}}{e}\right) = \varepsilon$ is the variation in the nominal exchange rate; $\left(\frac{\dot{y}_U}{y_U}\right) = \sigma_y^U$ and $\left(\frac{\dot{y}_A}{y_A}\right) = \sigma_y^A$ are the per capita growth of countries U and A; and $\left(\frac{\dot{X}_n}{X_n}\right) = \left(\frac{\dot{X}_m}{X_m}\right) = g$ is the common population growth rate, which is assumed to be equal in both countries. In this sense, the growth rate of per capita demand represented by equations (12) and (13) is:

$$\frac{\dot{a}_{i,m}^U}{a_{i,m}^U} = \eta_i\left(\sigma_i^U - \sigma_{i^*}^A - \varepsilon\right) + \beta_i\sigma_y^A + (\beta_i - 1)g, \qquad if\ p_i^U < ep_{i^*}^A \tag{14}$$

$$\frac{\dot{a}_{i^*,n}^U}{a_{i^*,n}^U} = \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i\sigma_y^U + (\phi_i - 1)g\right], \qquad if\ p_i^U > ep_{i^*}^A \tag{15}$$

where equation (14) indicates the growth rate of external demand for good i produced in country U and equation (15) expresses the growth rate of internal demand for country A's production of good i. From equation (14), for example, we can see that both an internal inflation rate that is less than external inflation plus currency appreciation ($\sigma_i^U < \sigma_{i^*}^A + \varepsilon$) and an income elasticity of exports (β_i) greater than unity can boost foreign demand.

We are now interested in the effects of variations in demand and prices on the national industry, especially when internal prices are greater than imported goods and a lack of demand may reduce national production and jobs. Therefore, for cases $p_i^U < ep_{i^*}^A$ and $p_i^U = ep_{i^*}^A$, the growth rate of demand for the ith consumption good in country U is given by Araujo (2013):

$$\frac{\dot{x}_i^U}{x_i^U} = \begin{cases} \theta_i^U r_i^U + (1 - \theta_i^U)\left[\eta_i\left(\sigma_i^U - \sigma_{i^*}^A - \varepsilon\right) + \beta_i\sigma_y^A + (\beta_i - 1)g\right] + g, & if\ p_i^U < ep_{i^*}^A \\ r_i^U + g & if\ p_i^U = ep_{i^*}^A \end{cases} \tag{16}$$

where θ_i^U represents the share of domestic demand in total demand for good i (Araujo, 2013, p. 135). However, this equation is incomplete. For the remaining case in which $p_i^U > ep_{i^*}^A$ (consequently, $a_{i,m}^U = 0$), we can apply the log function and take the derivative with respect to time from both sides of equation (11) and use equation (10):

$$\frac{\dot{x}_i^U}{x_i^U} = \frac{1}{1 + v\phi_i\mu_i}\left\{ r_i^U + v\left\{r_i^U - \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i\sigma_{y,-i}^U + (\phi_i - 1)g\right]\right\} + g\right\}, \quad if\ p_i^U > ep_{i^*}^A \tag{17}$$

where we defined $v = \frac{a_{i^*,n}^U}{\tilde{a}_{i,n}^U} = \frac{X_{i^*}^A}{X_{d,i}^U}$ as the ratio between imported and national product consumption of good i. The $\sigma_{y,-i}^U$ value is defined in appendix A.2 and indicates the rate of per capita income growth, in production terms, discounting good i. Furthermore, we consider the cases where $a_{i,n}^U - a_{i^*,n}^U > 0$, which means that the national good is attractive to this economy in comparison to the same good produced by the rest of the world or, in other words, that there is no full specialization of production in one exclusive country once the two have the necessary technology Freire (2019). This fact can indicate the national industry's power and express the limits on globalization. Otherwise, it means all units of good i are imported. This issue may arise if, over time, reduced national productivity decreases supply for domestic demand.

Therefore, in the limit, internal production tends to be null, indicating possible deindustrialization. These dynamics are at the core of structural changes[6], which can be temporary due to business fluctuations or "genuine", causing permanent alterations in the structure of production Hagemann (2012). Furthermore, within such a theoretical framework, the rise and decline of industries can be observed. This highlights the need for economic diversification, especially for developing countries, in order to create jobs and guarantee high levels of employment (Freire, 2019).

Therefore, to analyse the employment consequences, we can restate equation (5) to include an open economy:

$$E_i(t) = \begin{cases} \left[a_{i,n}(0) + \xi a_{i,m}(0)\right] a_{n,i}(0) N(0) e^{\left\{g + \theta_i^U r_i^U + (1-\theta_i^U)\left[\eta_i(\sigma_i^U - \sigma_{i^*}^A - \varepsilon) + \beta_i \sigma_y^A + (\beta_i - 1)g\right] - \rho_i^U\right\}t}, & if\ p_i^U < ep_{i^*}^A \\ a_{i,n}(0) a_{n,i}(0) N(0) e^{\left(g + r_i^U - \rho_i^U\right)t}, & if\ p_i^U = ep_{i^*}^A \\ \left[a_{i,n}(0) - a_{i^*,n}^U(0)\right] a_{n,i}(0) N(0) e^{\left\{g + r_i^U + v\left\{r_i^U - \left[\psi_i(\varepsilon + \sigma_{i^*}^A - \sigma_i^U) + \phi_i \sigma_{y,-i}^U + (\phi_i - 1)g\right]\right\}\frac{t}{1 + v\phi_i\mu_i} - \rho_i^U t}, & if\ p_i^U > ep_{i^*}^A \end{cases} \quad (5')$$

According to Pasinetti (1993), retirement at rate δ_i plays a role in the reorganization of employment over time between sectors. In this vein, to analyse the evolution of employment in each sector, we should compare the rates established in equation (5'). For an industry in which country U has no comparative price advantage or for a nontradable good or service, the evolution is given by

$$g + r_i^U + \delta_i^U \lesseqgtr \rho_i^U \quad (18)$$

which means that an increase (decrease) in jobs in the non-exporting sector occurs if the rate of job destruction from productivity enhancement is smaller (greater) than that of job creation from other factors. In other words, to maintain the macroeconomic stability represented in equation [1], an increase in consumption should compensate for technical progress. For the exporting sectors, the situation to be analysed is:

$$g + \theta_i^U r_i^U + (1 - \theta_i^U)\left[\eta_i\left(\sigma_i^U - \sigma_{i^*}^A - \varepsilon\right) + \beta_i \sigma_y^A + (\beta_i - 1)g\right] + \delta_i^U \lesseqgtr \rho_i^U \quad (19)$$

It must be noted that the increase in the demand coefficient is the weighted mean of internal and external demand. If we consider the increase in external demand to be greater than that in internal demand because A is related to an advanced country and country U has a price advantage, we can expect greater resilience to job destruction in the exporting sectors. Furthermore, the income elasticity of external demand (β_i) can enhance the labour performance of the exporting sector.[7] Therefore, the composition of the export basket plays a central role in employment issues.

Otherwise, if imports fill part of internal demand, we must compare:

$$\frac{g + r_i + v\left\{r_i - \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i \sigma_{y,-i}^U + (\phi_i - 1)g\right]\right\}}{1 + v\phi_i\mu_i} + \delta_i^U \lesseqgtr \rho_i^U \quad (20)$$

where we can expect $r_i - \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i \sigma_y^U + (\phi_i - 1)g\right] < 0$, as r_i represents the average increase in the per capita demand coefficient for good i and it must be less than strict demand for imports, which have a smaller price (we assume a negative correlation between price and demand). Additionally, $1 + v\phi_i\mu_i \geq 1$, which can reduce the effects of population

[6] These dynamics have received secondary attention from mainstream economists in explaining economic growth Araujo and Trigg (2015).

[7] For an analysis with endogenous income elasticities, see Magacho and McCombie (2020).

growth and demand increases. These effects imply that national jobs in sectors subject to external competition are more unstable and vulnerable to redundancy due to reduced demand.

In the short and medium term, displaced workers from the sector where innovations are more pronounced can be allocated, at least intergenerationally, to another industry – exporter or not. Furthermore, there is no 'steady-state' equilibrium but a permanent change in both output composition and the employment structure, and there is no endogenous mechanism that always assures full employment (Hagemann, 2012).

However, in the long run, we must deal with two factors. First, we cannot expect unlimited variations in the nominal exchange rate e. Therefore, we have $\varepsilon = 0$. Second, the condition presented in equation (7) must hold. These conclusions lead us to analyse endogenous productivity growth.

3. Endogenous productivity growth

The notion of endogenous productivity, as inspired by the Kaldor-Verdoorn law, has posed a challenge to the modelling of dynamic economic systems. In summary, there are two basic properties of growth (Setterfield, 2010): first, it is essentially demand led, with international trade being necessary to boost autonomous demand; second, the implications between actual and natural rates of growth are path dependent in relation to the historical development of technological regimes related to structural changes. Therefore, the role of demand should not be treated as exogenous Araujo and Trigg (2015) but as an inducer of the structural changes discussed in the previous section.

In this line, an important contribution was made by Rada (2007) with a bisectoral model examining the inability of developing countries to create productive employment in their economic systems. Our model proposed a solution by considering a multisectoral approach and assuming an endogenous rate of productivity growth, which is dependent on the rate of output growth. In Araujo, (2013), we linked the demand and supply sides by using Verdoorn's law. The productivity growth (ρ_i^U) of every sector in country U is given by:

$$\rho_i^U = \frac{\dot{q}_i^U}{q_i^U} = \gamma_i^U + \alpha_i^U \frac{\dot{X}_i^U}{X_i^U} \tag{21}$$

where $q_i^U = \left(\frac{1}{a_{n,i}^U}\right)$ indicates the productivity of sector i in country U. Therefore, $\left(\frac{\dot{q}_i^U}{q_i^U}\right) = -\left(\frac{\dot{a}_{n,i}^U}{a_{n,i}^U}\right)$, where γ_i^U and α_i^U are the autonomous growth of Verdoorn's relation and Verdoorn's coefficient, respectively. The last indicator indicates the sensitivity of productivity to economic growth. For country A, we assume exogenous output growth for every sector as follows:

$$\rho_{i^*}^A = \frac{\dot{q}_{i^*}^A}{q_{i^*}^A} = \gamma_{i^*}^A + \alpha_{i^*}^A \frac{\dot{X}_{i^*}^A}{X_{i^*}^A} = \gamma_{i^*}^A + \alpha_{i^*}^A \lambda_{i^*}^A \sigma_y^A \tag{22}$$

where $\lambda_{i^*}^A$ represents the sensitivity of productivity growth to the per capita income growth rate. Then, substituting equations (16), (17), and (22) into equation (21), we have:

$$\rho_i^U = \begin{cases} \gamma_i^U + \alpha_i^U\{\theta_i^U r_i^U + (1-\theta_i^U)[\eta_i(\sigma_i^U - \sigma_{i^*}^A - \varepsilon) + \beta_i\sigma_y^A + (\beta_i - 1)g] + g\}, & p_i^U < ep_{i^*}^A \\ \gamma_i^U + \alpha_i^U(r_i^U + g) & p_i^U = ep_{i^*}^A \\ \gamma_i^U + \frac{\alpha_i^U}{1+v\phi_i\mu_i}\{r_i + v\{r_i - [\psi_i(\varepsilon + \sigma_{i^*}^A - \sigma_i^U) + \phi_i\sigma_{y,-i}^U + (\phi_i - 1)g]\} + g\}, & p_i^U < ep_{i^*}^A \end{cases} \quad (23)$$

Rising productivity has an effect on prices in our model, which is central to the perspective on international competition, as seen in the previous section. Therefore, there is a two-way reinforcement between output growth and productivity gains to boost employment conditions, especially in the sectors that produce tradable goods. In this vein, we can derive this relation as in Araujo (2013):

$$\sigma_i^U = \sigma_w^U - \rho_i^U \quad (24)$$

$$\sigma_{i^*}^A = \sigma_w^A - \rho_{i^*}^A \quad (25)$$

which indicates growth in prices in sector i (σ_i^U, $\sigma_{i^*}^A$) if the rate of growth of nominal wages (σ_w^U, σ_w^A) is greater than productivity growth. If the productivity gains in sector *i* are greater than the increases in real wages in the overall economy, prices decrease, which augments demand, affecting jobs and real per capita income. This is the core of the cumulative causation represented by our model. For the sake of simplicity, we assume that $\sigma_w^U = \sigma_w^A$, albeit not in terms of relative purchasing power parity (RPPP) because this is usually valid only over very long periods. In other words, we do not assume that the exchange rate moves exactly in line with prices in either country ($\sigma_i^U - \sigma_{i^*}^A - \varepsilon \neq 0$). Therefore, we can restate equation (23) as follows:

$$\rho_i^U = \begin{cases} \frac{\gamma_i^U + \alpha_i^U\{\theta_i^U r_i^U + (1-\theta_i^U)\eta_i(\gamma_{i^*}^A - \varepsilon) + \Omega_i^A\sigma_y^A + (1-\theta_i^U)(\beta_i - 1)g + g\}}{1+(1-\theta_i^U)\eta_i\alpha_i^U}, & if\ p_i^U < ep_{i^*}^A \\ \gamma_i^U + \alpha_i^U(r_i^U + g) & if\ p_i^U = ep_{i^*}^A \\ \frac{\gamma_i^U + \frac{\alpha_i^U}{1+v\phi_i\mu_i}\{r_i + v\{r_i - [\psi_i(\varepsilon - \gamma_i^A - \alpha_{i^*}^A\lambda_{i^*}^A\sigma_y^A) + \phi_i\sigma_{y,-i}^U + (\phi_i - 1)g]\} + g\}}{\chi_i^U}, & if\ p_i^U > ep_{i^*}^A \end{cases} \quad [23']$$

Where $\Omega_i^A = (1-\theta_i^U)(\eta_i\alpha_i^U\lambda_{i^*}^A + \beta_{i^*}^A)$, as in Araujo (2013) and $\chi_i^U = 1 + \frac{\alpha_i^U v\psi_i}{1+v\phi_i\mu_i}$. In addition, production in sector i is smaller when a market is exposed to international competition and has a greater price, and the sector's productivity growth rate tends to be smaller than in a situation with better price competitiveness, which is central to the theory of cumulative causation (Araujo and Trigg, 2015).

Equation (23') offers additional elements to the equations related to employment. From equation (19), the price advantage enhances both production and productivity growth. If the former is greater (or smaller) than the second, employment increases (or decreases) in sector *i.* On the other hand, the equation shows us that in an open economy, productivity gains tend to maintain a country's leadership in that sector by lowering prices. This can be represented by a cumulative causation process (Setterfield, 2010), where rapid demand growth induces increased returns and productivity growth. Then, there is increased export demand and, consequently, output growth. Furthermore, this issue is more noticeable for goods with high aggregated values, which are subject to postponed effects under Engel's law, leading, in the medium and long run, to constant increases in employment. Therefore, increases in labour productivity may be good for workers by allowing greater international demand, in line with the core of the neo-Kaldorian approach (Araujo and Trigg, 2015).

For the relation represented by [20], the reduction in productivity growth is followed by an output reduction in sector i. Similarly, if the decrease in production is smaller (or greater) than the slowing productivity growth, the employment effect is positive (or negative). However, reduced productivity tends to further raise the relative international prices of domestic production. In the medium and long run, this may lead to a reversal trend of an increase in employment and, consequently, fewer jobs in the sector due to international competition.

Hence, international trade drives additional instability in the labour market since the Verdoorn impact on employment is not straightforward. Moreover, the price-dependent analysis adopted here shows that the immediate impact on jobs implies relevant questions about the reallocation of workers and the quality of occupations. However, some patterns emerge: 1) a short-run increase in employment caused by reduced productivity gains in comparison to job demand may, in the medium and long run, reduce national participation in the sector subject to international competition and, therefore, be harmful to workers; 2) sectors with reduced aggregate value may suffer, first, the effects of Engel's law, reversing the previous pattern of increasing employment; and 3) productivity gains are not automatically adverse for workers if connected with increased (international) demand.

4. Concluding remarks

This paper reinterprets Araujo (2013) for the case where $p_{i0}^{U} > ep_{i^*}^{A}$, i.e., domestic prices are higher than external prices. The analysis shows that in this case, imports may discourage domestic job creation. On the one hand, the employment discouragement effect worsens when the affected sectors have a significant weight on overall output and employment. On the other hand, endogenous productivity growth provides some counterbalancing effects as long as it is associated with higher external demand. These results cast doubt on the validity of the thesis that trade openness is always positive for economic growth and thus domestic job creation.

From a macroeconomic point of view, this case also implies a tendency towards chronic trade deficits, as imports will systematically exceed exports. This shows the limits of globalization as an engine of growth, since domestic income, employment levels and the income distribution are adversely affected, as shown in section 3. This analysis can also help explain the partial deterioration of jobs and productivity in underdeveloped countries, especially in the tradable sector, which is subject to international competition. These dynamics tend to move resources and workers to sectors with lower prices, primarily nontradable goods and services, leading to lower productivity gains. As a future project, multisectoral empirical validations of the model could be attempted for both developed and developing countries.

Appendix A

A.1. Term of population equalization

The equalization factor between internal and foreign populations (ξ) is derived from the source of the national production of good i by country U, represented by X_i^U, to respond to internal $X_{d,i}^U$ and foreign $X_{d,i}^A$ demand d from country A.

$$X_i^U = X_{d,i}^U + X_{d,i}^A$$

By dividing both sides of the above equation by the population, performing some algebraic manipulations and using the definition of per capita demand, we have:

$$\frac{X_i^U}{X_n} = \frac{X_{d,i}^U}{X_n} + \frac{X_{d,i}^A}{X_n} = \frac{X_{d,i}^U}{X_n} + \frac{X_{d,i}^A}{X_m}\frac{X_m}{X_n} = \frac{X_{d,i}^U}{X_n} + \frac{X_m}{X_n}\frac{X_{d,i}^A}{X_m} = a_{i,n} + \xi a_{i,m}$$

where $\xi = X_m/X_n$ is an equalization factor between the internal (X_n) and foreign populations (X_m).

A.2. Production growth rate in the case of $p_i^U > ep_{i^*}^A$

Equation (17) can be derived as follows by applying the log function and taking the derivative concerning time from both sides of equation (11) and, finally, using equation (10).

$$\frac{\dot{X}_i^U}{X_i^U} = \frac{\dot{a}_{i,n}^U - \dot{a}_{i^*,n}^U}{a_{i,n}^U - a_{i^*,n}^U} + g = \frac{\dot{a}_{i,n}^U}{a_{i,n}^U}\frac{a_{i,n}^U}{\tilde{a}_{i,n}^U} - \frac{\dot{a}_{i^*,n}^U}{a_{i^*,n}^U}\frac{a_{i^*,n}^U}{\tilde{a}_{i,n}^U} + g$$

$$\frac{\dot{X}_i^U}{X_i^U} = \frac{r_i^U a_{i,n}^U}{\tilde{a}_{i,n}^U} - \frac{\left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i\sigma_y^U + (1-\phi_i)g\right]a_{i^*,n}^U}{\tilde{a}_{i,n}^U} + g$$

$$\frac{\dot{X}_i^U}{X_i^U} = r_i^U(1+v) - \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i\sigma_y^U + (\phi_i - 1)g\right]v + g$$

$$\frac{\dot{X}_i^U}{X_i^U} = r_i^U + v\left\{r_i^U - \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i\sigma_y^U + (\phi_i - 1)g\right]\right\} + g$$

$$\frac{\dot{X}_i^U}{X_i^U} = \frac{1}{1+v\phi_i\mu_i}\left\{r_i^U + v\left\{r_i^U - \left[\psi_i\left(\varepsilon + \sigma_{i^*}^A - \sigma_i^U\right) + \phi_i\sigma_{y,-i}^U + (\phi_i - 1)g\right]\right\} + g\right\}, \quad if\ p_i^U > ep_{i^*}^A \tag{17}$$

where, in the second step, we use the fact that $\frac{\dot{a}_{i,n}^U}{a_{i,n}^U} = r_i$. In the third step, we define $v = \frac{a_{i^*,n}^U}{\tilde{a}_{i,n}^U} = \frac{X_{i^*}^A}{X_{d,i}^U}$ as the ratio between imported and national product consumption of good i.

The $\sigma_{y,-i}^U$ value is defined by considering the per capita income growth of country U (σ_y^U) as dependent on the growth of internal production for every sector i, and we are interested in isolating the effect of a given sector i. First, per capita total production (y^U), in real terms, is:

$$\frac{Y^U}{X_n} \equiv y^U = \frac{1}{X_n}\sum_{i=1}^{n-1} X_i^U$$

Applying the natural log operation $i =$ to both sides, we have:

$$ln(y^U) = ln\left(\sum_{i=1}^{n-1} X_i^U\right) - \ln(X_n)$$

Taking the derivative concerning time, we have:

$$\sigma_y^U \equiv \frac{\dot{y}^U}{y^U} = \sum_{i=1}^{n-1}\left(\frac{\dot{X}_i^U}{\sum_{i=1}^{n-1} X_i^U}\right) - \frac{\dot{X}_n}{X_n} = \frac{1}{Y^U}\sum_{i=1}^{n-1}\dot{X}_i^U - g$$

Defining $\mu_i = \frac{X_i^U}{Y^U}$ as the participation of the productive sector i in the total product, we have:

$$\sigma_y^U = \sum_{i=1}^{n-1}\frac{\dot{X}_i^U}{X_i^U}\mu_i - g$$

Finally, isolating for some sector i and considering i, j integers and $i, j \in [1, n-1],\ i \neq j$, we can rewrite the previous equation as

$$\sigma_y^U = \frac{\dot{X}_i^U}{X_i^U}\mu_i + \sum_{j=1}^{n-1}\frac{\dot{X}_j^U}{X_j^U}\mu_j - g = \frac{\dot{X}_i^U}{X_i^U} + \sigma_{y,-i}^U$$

where we define $\sigma_{y,-i}^U \equiv \sum_{j=1}^{n-1}\frac{\dot{X}_j^U}{X_j^U}\mu_j - g$.

Appendix B: Ricardo's 2013 paper

Ricardo's paper expanded Pasinetti's structural economic dynamics (SED) approach by raising international trade hypotheses and considering different price levels to analyse technological gaps between rich and poor countries (which he called uneven and advanced countries). The main objective was to add to the SED framework a reconciliation between cumulative causation and the balance of payments constrained view.

His approach applied Verdoorn's law to consider cumulative causation concerning endogenous structural change. At the core of the model, exogenous foreign demand promotes productivity gains by increasing returns to scale. The central discussion of our paper is related to equation (18) on the growth rate of demand for the i^{th} consumption good in country U (the variables are explained in equation (13) in our paper):

$$\frac{\dot{X}_i^U}{X_i^U} = \begin{cases} \theta_i^U r_i^U + (1-\theta_i^U)\left[\eta_i\left(\sigma_i^U - \sigma_{i^*}^A - \varepsilon\right) + \beta_i\sigma_y^A + (\beta_i - 1)g\right] + g, & if\ p_i^U < ep_{i^*}^A \\ r_i^U + g & if\ p_i^U = ep_{i^*}^A \end{cases} \quad \text{(B.1)}$$

where he analysed the effects on economic growth by considering internal prices smaller than or equal to external prices.

In his analysis, when the internal price is greater than external one, the rate of production growth of sector i is given by the growth rate of the labour force and the growth rate of domestic demand. Otherwise, if country U has a price advantage, the rate of output growth is the weighted mean of domestic and foreign demand growth rates plus the labour force growth rate.

However, unlike us, he only mentioned the effects on employment; these were not the central theme of his article. Moreover, the case of $p_i^U > ep_{i^*}^A$ is not discussed. From equation (B.1), he developed the technological progress in each sector of country U in terms of differences in the relative prices, as in equation (19) in his paper (and equation (23) in ours).

$$\rho_i^U = \begin{cases} \gamma_i^U + \alpha_i^U\{\theta_i^U r_i^U + (1-\theta_i^U)[\eta_i(\sigma_i^U - \sigma_{i^*}^A - \varepsilon) + \beta_i\sigma_y^A + (\beta_i - 1)g] + g\}, & p_i^U < ep_{i^*}^A \\ \gamma_i^U + \alpha_i^U(r_i^U + g) & p_i^U = ep_{i^*}^A \end{cases}$$

Thus, it is possible to verify the growth behaviour by considering Thirwall's law presented by Dixon and Thirwall (1975) in a cumulative causation framework. Furthermore, in the presence of a price comparative advantage, the technological development of sector i becomes a function of internal demand and the income elasticity of foreign demand. The author concluded that international competition provides incentives to keep costs low, inducing technological change.

After that, following Araujo and Lima (2007), he used Verdoorn's law to expand the multisectoral version of Thirwall's law by considering the technological process. Thus, he considered a new version of Thirwalls's law enriched by technological progress that permits evaluation of increasing growth rates and high levels of productivity growth.

The cumulative causation process permitted him to conclude on page 138 that "the essence of the argument is that once a region gains a growth advantage its advantage will tend to be sustained through the process of increasing returns that growth itself induces the Verdoorn effect. Besides, according to the view presented herein it was possible to combine Thirlwall's Law and Verdoorn's Law, which is evidence that there are benefits from combining insights from the various strands of Post-Keynesian growth theory".

In our paper, we highlight the implications of fragile price competitiveness for domestic industry.

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