Demand-led Industrialisation Policy in a Dual-Sector Small Open Economy

Önder Nomaler[*], Danilo Spinola[**] & Bart Verspagen[***]

This version of 23 November 2023

Abstract

This article models the process of structural transformation and catching-up in a demand-led Southern economy constrained by its balance of payments. Starting from the Sraffian Supermultiplier Model, we model a dual-sector small open economy with a traditional and a modern sector that interacts with a technologically advanced Northern economy. We propose two (alternative) autonomous elements that define the growth rate of this demand-led economy: government spending and exports. Drawing from the Structuralist literature, productivity in the technologically laggard Southern economy grows by absorbing technology from the Northern economy, by both embodied and disembodied spillovers, and potentially closing the technology gap. The gap affects the income elasticity of exports, bringing a supply-side mediation to the growth rates in line with the Balance of Payments Constrained Model. We observe that a demand-led government policy plays a central role in structural change, pushing the modern sector to a larger share of employment than what results under export-led growth. Such a demand policy is the only way in which partial catching up (in productivity and GDP per capita) can result, and this is facilitated by a global market place in which the balance of payments constraint is relatively soft.

Keywords: Industrialisation; Catching-up; Balance of Payments constrained growth; Sraffian Supermultiplier; Demand-led growth; Dual economy.

JEL: O41, E12, E61

[*] United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-Merit), nomaler@merit.unu.edu
[**] Birmingham City University, UNU-Merit & University of Johannesburg, danilo.spinola@bcu.ac.uk
[***] Maastricht University, b.verspagen@maastrichtuniversity.nl

1. Introduction

The process of structural transformation involves moving from a dominance of traditional sectors to modern sectors of production. Here, "traditional sectors" refers to economic activities with low (or no) productivity growth that can be undertaken without much capital investment or formal education. Subsistence farming is a typical example, but certain service activities in an urban context, such as street vending, also fall under this heading. The "modern sector" consists of manufacturing, where productivity growth can be high, and investment in physical and human capital is necessary, along with some of the more dynamic services sectors such as telecommunications (Lavopa and Szirmai, 2018). Thus, since the (first) Industrial Revolution, structural transformation has been connected directly with productivity increases, urbanisation, and moving from primary to manufacturing activities (Deane, 1979). These ideas can be traced back to Lewis (1954) and structuralist thinkers such as Prebisch (1950), and are now prominent in thinking about development.

The industrial revolution emancipated some societies from the Malthusian trap (Kögel & Prskawetz, 2001), generating productivity growth, increases in wages, and improvements in science and in life conditions (increased life expectancy, educational levels) (Hartwell, 2017). But this process has been quite uneven around the globe (Fagerberg, 1994), and while some countries have managed to achieve a strong process of structural transformation, many other economies in developing regions still struggle to start and advance their own process of catching up (Fagerberg & Godinho, 2005). Thus, how economies can manage to leave a pre-industrial, fully traditional economy behind and move towards the constitution of modern high-productive sectors has become a crucial question with deep policy impact.

Some features of the process of structural transformation have shown a degree of commonality. Laggard economies that successfully catch up (as in the case of South Korea) are the ones that have managed to absorb and adapt foreign technology (Cimoli & Porcile, 2014; Cimoli et al., 2019; Fagerberg, 1994). The recent experiences of catching up in developing economies are usually connected to a strong government presence, as we see in China. Countries that have developed a strong modern sector have managed to relax their external constraints by diversifying their productive structure and increasing their growth rates to be compatible with balance-of-payments constraints (Thirlwall, 1979; Sasaki, 2021).

In terms of policy, a prominent idea is that of the so-called developmental state (Wade, 2018), which, broadly speaking, refers to a government that takes an active and leading role in organising structural transformation. The cases of South East Asian nations such as Japan, South Korea, and Taiwan, which realised quick structural transformation and the associated rapid economic growth, are seen as key examples of this type of policy. In the idea of the developmental state, the emphasis lies mostly on supply-side policies, for example aimed at promoting technological learning, often through the adoption of foreign knowledge, the selection of specific sectors as policy targets, and stimulating exports.

In this paper, we want to analyse the potential influence of a demand-led policy for structural transformation or industrialisation. The idea is that the development of a modern sector may not only be stimulated by foreign demand (exports), but also by domestic demand. Domestic demand may work through the wages of workers in the modern sector (i.e., a multiplier process), but government demand for modern-sector products may reinforce this effect. Our research question is, therefore, whether a demand-led policy for structural transformation (or industrialisation) may work and, if so, under which circumstances and how it will influence the growth rate of the economy. Although our approach will not address the issue of supply-side policy, we do not want to suggest that supply-side policy is unimportant. We only want to bring forward the (theoretical) implications of a demand-led policy while not underrating the importance of supply-side policy for industrialisation. Indeed, some of the parameters in our model that are shown to determine the extent to which demand-side policies can be effective for catching up, are likely to be affected by supply-side policies.

Our model of structural transformation is based on a range of interconnected theoretical approaches. The backbone of the model derives from the Sraffian Supermultiplier Model (SSM; Freitas & Serrano, 2015), which offers a demand-led long-run growth framework that has recently gained momentum. The SSM is a macroeconomic model with a fully endogenous investment function (accelerator mechanism) that (a) increases the traditional Keynesian multiplier, generating higher multiplicative effects of autonomous spending, and (b) proposes that firms plan their production capacity with reference to a long-run capacity-utilisation rate.

We expand the SSM model by splitting the economy into a dual-sector structure composed of a low-productivity traditional sector and a modern, advanced sector. This part of our model is inspired by structuralist thinking, in particular by Porcile (2021) and Lavopa (2015). From an initial situation in which the economy consists largely of the traditional sector, we observe, under certain conditions (that we discuss in this paper), transition dynamics towards structural modernisation. Government intervention in the form of a demand policy brings the economy on a path towards a larger modern sector. This government role goes in the same direction as Deleidi and Mazzucato (2019) and Freitas and Christianes (2020). Without autonomous government spending, the economy stays trapped in a low share of the modern sector.

In reaching this result, we expand the original SSM model into one of a Southern small open economy that interacts with the rest of the world through (1) international trade (imports and exports) and (2) absorption of technological knowledge, as the Southern economy is a technologically laggard as in the structuralist framework (Cimoli & Porcile, 2014). The presence of a technological gap, however, creates important catching-up opportunities (Verspagen, 1992; Lee & Malerba, 2017). Also, this Southern economy faces a balance of payments restriction in the sense of a limit on accumulated foreign debt as a result of trade, which allows us to include elements from the Balance of Payments Constrained model (BPCM) (Thirlwall, 1979).

The paper is organized in the following way: after this introduction, Section 2 presents a brief review of relevant literature. In Section 3, we introduce our model. In Section 4, we present the steady state results (there are four possible steady state regimes, of which one appears unstable). Section 5 discusses the results in light of the debates, as well as the specificities of the model. Finally, we conclude the paper in Section 6. Appendix I provides the formal derivation of the steady states, and Appendix II gives details about some simulation experiments.

2. Literature Review

2.1. Dual sector economy

The process of economic development in industrial economies involves a strong sectoral reallocation towards dynamic activities. Lewis (1954) modelled this process of structural transformation in his dual-sector dynamic model, focusing on the transition from an economy dominated by a traditional, low-productivity agricultural sector to one containing a modern, industrial urban sector. In the Lewis model, an endogenous dynamic of capital accumulation gives rise to the modern sector that absorbs employment from the traditional sector, thereby increasing the average productivity of the economy.

Prebisch (1950) and ECLAC (1955), pioneers in the Latin American Structuralist (LAS) literature, position a similar kind of dynamic argument in the context of a global Center-Periphery system where the diversified North (Center) takes the lead in innovation (technical change) while the specialized South (periphery) lags behind (see Rodriguez, 2007). In the LAS framework, the productive structure of the Center/North constantly diversifies (Lavopa, 2015), while the Southern economy benefits only in a partial way from the technological change done in the North (Botta, 2009). The adoption of cutting-edge technologies in the South is fragmented, localized, and concentrated in export activities (Porcile, 2021), centred only on a few modern industries that absorb a small part of the workforce (Prebisch, 1950; Pinto, 1976; Sunkel, 1978). The South further concentrates its economic activities in less technology-intensive sectors, such as commodity production, while its labour market remains highly segregated, with a high share of workers in activities with very low productivity (subsistence sector). In summary, the North is diversified and shows homogeneous labour productivity across sectors, while the South only specializes in a narrow set of commodities with large differences in labour productivity within and between sectors (Cimoli & Porcile, 2014).

The central role of manufacturing as a driver of economic growth has recently been reinforced by authors such as Szirmai (2012) and Rodrik (2016). While some economies in Africa and Asia, such as Somalia, Ethiopia and Kenia, are trapped in low development with a very large traditional primary sector (Felipe et al., 2012), some other economies, especially in Latin America, have observed a partial movement towards the adoption of modern activities. Thus, the Center-Periphery dynamics of the LAS may also be interpreted as a middle-income trap (Felipe et al., 2012; Andreoni & Tregenna, 2020), the severity of which seems to be stressed by the fact that some of these economies now suffer from premature deindustrialisation (Rodrik, 2016; Tregenna, 2016).

The transition to a modern economy, out of a middle- or low-income trap, is far from automatic, and it may not occur at all. The lack of conditions to allow for a widespread process of structural transformation creates barriers to the transition, while the economies stay trapped in traditional, low-tech activities. The way to overcome these barriers will then depend on the institutional and structural conditions of the economy regarding the external sector and the role of government as a development agent in the process.

Also, as observed in the structuralist theory, urbanisation in developing economies has resulted in the emergence of a large informal sector, mostly situated in the service sector (Lavopa, 2015). A high informality and the predominance of traditional activities in cities strengthen inequality, being the source of the widespread emergence of slums and other marginalised urban structures (Marx et al., 2013). Thus, Lavopa (2015) and Lavopa and Szirmai (2018) propose an update to the concepts of modern and traditional in the dual-sector framework of the Lewis model. The authors split the service sector by the degree of productivity of each sub-sector, labelling those as modern or traditional sectors. Using this new dichotomy, we are able to capture the problem of structural transformation in a unified framework, detaching it from a classical view mostly related to urbanisation.

2.2. The External Sector and the Balance of Payments Constraint

The external sector and the balance of payments play a large role in the Center-Periphery dynamics of the LAS. Prebisch (1950) focuses on the role of international price dynamics, in particular a tendency of decline in the terms of trade for the South, as traditional goods tend to become cheaper faster than modern goods. On the other hand, the Balance-of-Payments Constrained Model (BPCM) of economic growth, developed by Thirlwall (1979) and McCombie and Thirlwall (2004), abstracts from price dynamics by assuming that in the long run, the real exchange rate does not matter (for an extensive review of this literature, see Blecker & Setterfield, 2019).

In the BPCM, growth is constrained in the long run by the need for stability in the external sector. In the approach known as Thirlwall's law (Thirlwall, 1979; McCombie, 2012), the constraint expresses itself through the ratio between the income elasticities of demand for exports and imports. The literature on the BPCM has been a central contribution of the Keynesian tradition, with relevant empirical evidence, as can be observed in the reviews by Blecker and Setterfield (2019) and Blecker (2021).

While the original Thirlwall's law (Thirlwall, 1979) imposes a strict dynamic balance of payments equilibrium, subsequent literature has relaxed this harsh restriction. Thirlwall and Hussain (1982) allow trade deficits by also incorporating capital inflows, which then become part of the constraint. McCombie and Thirlwall (1997), Moreno Brid (1998), and Barbosa-Filho (2001), among others, extended this to an approach where the BOP restriction is stated in terms of a stable ratio of (accumulated) trade deficits to GDP. Such a constraint is 'softer' than the original Thirlwall's law, with a role for international financial markets in determining the harshness (or softness) of the constraint.

The external sector, and in particular imports, has also played a large role in the structuralist debate on the supply side of the economy. In Hirschman's (1968) recommendation of *import substitution*, the international division of labour is changed in favour of the periphery when these countries diversify by producing domestically the high-tech goods that they used to import (de Paula & Jabbour, 2020). That argument, despite being very much criticized later by pro-liberalization economists (Bruton, 1998) and by evolutionary scholars (Fajnzylber, 1990), was partially responsible for policies that resulted in a wave of industrialization in the developing world, as an important part of the modern sector started taking off. Critics of this approach highlight that this take-off was only partial, and never properly resulted in complete catching-up (leapfrogging), but ended up leading to a middle-income trap (Lin, 2017).

The import-substitution process relies to an important extent on the idea that imports incorporate foreign technology (e.g., Prebisch, 1950), and hence that the successful substitution of these imports will bring technological mastery. Thus, the imports of capital goods, as long as they have not been substituted by domestic technological capabilities, can also be growth-enhancing (Ziesemer, 1995; Hallonsten & Ziesemer, 2016; Lee, 2019), leading to an additional factor in the balance of payments that should be addressed (Ziesemer & Hallonsten, 2019). The mainstream literature on endogenous growth also links the imports of capital goods to long-run growth (Lee, 1995; Carrasco & Tovar-García, 2021; Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991).

2.3. Technology Gap Growth Models, neo-Structuralism and Industrial Policy

Besides imports, there are also other channels of technology diffusion from the centre to the periphery. This has been the topic of the literature on long-run growth and technology gaps (e.g., Abramovitz, 1986; Fagerberg, 1994; Fagerberg and Godinho, 2005; Verspagen, 1992). In this approach, technology flows can lead to the development of peripheral countries, but only if technological congruence and domestic capabilities in the developing country are high enough (Abramovitz, 1986). If this is the case, then the technology gap between the centre and the periphery will gradually be closed by a process of technology adoption (and adaptation), leading to structural change as envisaged in the structuralist literature that we briefly discussed above.

Porcile (2021) observes a convergence between this literature and the LAS, leading to a neo-structuralist approach. In the theoretical approach that he proposes, Thirlwall's law, as a representation of the equilibrium long-run growth rate in developing economies, is combined with imperfect knowledge flows from the centre to the periphery as a result of the technology gap that exists between the two. In this way, we see the idea emerging that a core reason behind international inequality is the interconnected existence of a Center-Periphery division of labour and a Center-Periphery technology gap.

In an early approach in this vein, Cimoli & Porcile (2014) link to the evolutionary discussion on the economics of innovation through the endogenisation of the income elasticity ratio (see also Lavopa, 2015; Porcile & Spinola, 2018). In this way, the income elasticities of demand for exports and imports are seen as related to the degree of diversification of the economy and the degree of technological capabilities. Countries that have a higher income elasticity of demand for exports are the ones that export more advanced manufactured products with more embedded knowledge and a higher degree of complexity. The empirical literature indeed highlights a positive correlation between products with higher technology intensiveness and higher income elasticity of demand (Dosi et al., 1990; Gouvea and Lima, 2010; Cimoli & Porcile, 2014; Porcile & Yajima, 2021). The higher the number of products a country can produce, the higher the income elasticity ratio.

Industrial policy is often seen as the main way of stimulating technology adoption and industrialisation, or, in short, modernisation of a developing economy (e.g., Nelson & Pack, 1999; Cimoli et al., 2009). One way in which this can be done is via the so-called developmental state (e.g., Wade, 2018). The idea of the developmental state relies on the idea that markets are not vectors of structural change, but rather of economic specialisation (Chang, 1994). In order to advance with a process of structural change (industrialisation and an increase in modern activities), developing economies need to rely on strong government coordination, goal setting and mobilisation of private actors through government policy. Despite some failures, the main countries that have managed to catch up relied on developmental policies (Altenburg, 2011), as in the case of South Korea, Taiwan and Singapore (Wade, 2018).

The debate on industrial policy has been controversial, with a recent resurge (Aiginger & Rodrik, 2020), but it enters as a fundamental institutional element to lead to the process of catching up and structural change in developing economies (Andreoni & Chang, 2019; Landesmann & Stöllinger, 2019; Ocampo & Porcile, 2021). The need to create an institutional framework and direct resources to the construction of modern sectors has been shown in the literature as being fundamental in the transition from a low- and low-middle-income country to a middle- or high-income country, and the state, in its developmental face (Caldentey, 2008), has played a central historical role in this process.

2.4. Demand and the Sraffian Supermultiplier Model (SSM)

While industrial policy and the developmental state link primarily to the supply side of the economy, the Keynesian tradition (Blecker & Setterfield, 2019) stresses the role of demand, including government demand. This approach starts from a conception of the economic system as possibly suffering from a negative spiral of demand caused by expectations in a monetary context, in which Say's law is not valid (Davidson, 1972). Such a system needs an injection of demand that can reverse its path in the direction of full employment. The Keynesian view is centred on the short-run mechanisms that may lead the economy to a crisis, and then governmental spending acts as a way to recompose demand and expectations.

One particular incarnation of the Keynesian argument that has attracted much recent attention is the so-called Sraffian Supermultiplier Model (SSM). The SSM approach consists of a demand-led growth model as initially proposed by Freitas and Serrano (2015). In this model, investment is fully endogenized, and the role of demand in growth is reduced to a single parameter, the growth rate of autonomous (i.e., not dependent on current income) consumption demand. Firms aim at maintaining a certain degree of idle capacity, allowing them to react to changes in demand conditions. In the long run, capacity utilisation converges to an exogenous rate. The model stabilises the relationship between productive capacity and aggregate demand by adjustments of the marginal propensity to invest. Because this propensity is an endogenous variable, it enters the multiplier that determines the short-run level of output, resulting in the term supermultiplier.

In the SSM, investment follows a pure accelerator mechanism (capital accumulation induced by income) with no autonomous component. Consumption (either private or public) has an autonomous component that often (e.g., Freitas and Serrano, 2015; Lavoie, 2016; Alain, 2015, 2019) grows at an exogenous growth rate. The short-run level of output adjusts to make savings equal to investment ex-post. Growth is demand-led not only in the short but also in the long run, and the growth rate is equal to the exogenous growth rate of autonomous demand. Capital accumulation (given the equilibrium utilisation rate) converges to this rate. A number of subsequent papers endogenized autonomous spending.[1] The endogenous mechanisms that were proposed include

[1] We follow the usual convention of the supermultiplier literature in defining autonomous spending as spending that is independent of current period output/income. If autonomous spending depends on other factors than current income, it is not exogenous. Caminati and Sordi (2019, p. 406) refer to such "endogenous autonomous" demand as "semi-autonomous".

autonomous consumption related to the accumulated wealth of the workers (Brochier & Silva, 2019; Nomaler, Spinola & Verspagen, 2021) and R&D investments (Caminati & Sordi, 2019).

The role of government spending in growth has been well-developed by Keynesian authors (e.g., Kaldor, 1957; Blecker & Setterfield, 2019). But government spending may also have a supply-side effect, as in Deleidi and Mazzucato's (2019, 2021) SSM, where autonomous government spending takes the form of mission-oriented science and technology policy (Mazzucatto, 2018), which creates, coordinates, and funds research and investment projects that lead to long-run productivity increases (Mazzucatto, 2011).

In this way, a supply-side policy, such as a science and technology policy or industrial policy, may also enhance growth and development through the demand side. This leads directly to our interest in whether a Keynesian demand policy can also be used to stimulate development and structural change in the sense of Porcile's neo-structuralist perspective. In the next section, we will construct a dual economy structuralist technology model with an SSM backbone to explore this interest.

3. Model

We consider a dually-structured Southern economy, with a modern and a traditional sector, which interacts with the rest of the world through imports and exports, in line with Nah and Lavoie (2017). Although both the modern and the traditional sectors exist in the country, the traditional sector dominates the economy, and the question we pose is how a demand-led government policy can increase the share of the modern sector in the economy. We specify, analyse and simulate the model in discrete time.

In the traditional sector, workers consume what they produce, i.e., although the sector is counted in GDP, there are no savings, no investment, no imports, and no exports. In this setting, as in the original Lewis approach, we only need to consider the role of the traditional sector as an absorber of workers who cannot find employment in the modern sector. Thus, we start the model exposition by writing the standard macroeconomic income identity, which holds for the modern sector irrespective of the size of the traditional sector:

$$Y_t = C_t + I_t + Z_{Gt} + X_t - M_t \tag{1}$$

where Y is output of the modern sector, C is total consumption of modern sector output, I is total investment in the modern sector (and consisting of modern sector output), Z_G is autonomous government spending on modern sector output, X is total exports of modern output and M total imports of modern sector products of the North. The subscript t indicates time. The corresponding income identity for the traditional sector would be

$Y_t^T = C_t^T$, where the superscript T indicates the traditional sector, but this identity plays no further role in the analysis.

3.1. Short-run output and the supermultiplier

We start the analysis by looking at how the supermultiplier determines output in the short run. Private consumption is fully endogenous, depending only on disposable income:

$$C_t = c(1 - t_t)Y_t \tag{2}$$

where $0 < c < 1$ is the marginal propensity to consume, and t is the tax rate. Following the supermultiplier literature (Freitas & Serrano, 2015), investment is also fully endogenous, following an accelerator mechanism by which the marginal propensity to invest responds to changes in capacity utilization:

$$I_t = h_t Y_t \tag{3}$$

in which h_t is the (endogenous) marginal propensity to invest.

Next, imports M are fully endogenous and a function of current-period modern sector output:

$$M_t = m_t Y_t \tag{4}$$

Note that the propensity to import, m, is time-varying (we will provide an equation to endogenize it below). Exports (X_t) are autonomous. Government spending (Z_G) is another component of autonomous spending, representing an important component of long-run growth in the SSM framework. It is defined as proportional to the capital stock, following an approach similar to Nomaler et al. (2021):

$$Z_{Gt} = \zeta_t K_t \tag{5}$$

in which ζ is the marginal propensity of government spending out of economy-wide wealth given by the capital stock.

The income identity (Equation 1) now becomes

$$Y_t = c(1 - t_t)Y_t + h_t Y_t + Z_{Gt} + X_t - m_t Y_t \tag{6}$$

This can be used in the conventional way to derive modern sector output as the product of autonomous spending and the supermultiplier:

$$Y_t = (Z_{Gt} + X_t)\Omega_t \tag{7}$$

in which the multiplier is given by $\Omega_t \equiv \frac{1}{1-c(1-t_t)-h_t+m_t}$.

3.2. Capital and the labour market

We now have to define the way in which the key variables of the model change in the long run. We use forward differencing throughout the analysis, i.e., $\Delta V_t = V_{t+1} - V_t$ for any variable V. We start by specifying an equation for the change of h, where we are fully in line with the supermultiplier literature:

$$\Delta h_t = h_{t+1} - h_t = \gamma(u_t - \mu) \tag{8}$$

where $0 < \mu < 1$ is the desired long-run capacity utilization ratio, $0 < \gamma < 1$ is a parameter, and u is the capital utilization rate, which is defined as $u = \frac{Y}{Y_K}$, where $Y_K = \frac{K}{v}$ is full-capacity output, and $v > 0$ is the incremental capital-output ratio. With all this, we have

$$u_t = v\frac{Y_t}{K_t} \tag{9}$$

Capital accumulates in terms of new investments minus depreciation:

$$\Delta K_t = I_t - \delta K_t = h_t Y_t - \delta K_t \tag{10}$$

where δ is the depreciation rate (and we still use the forward difference). Equations (3), (8) and (10) act as a mechanism to take capacity utilization to the long-run level of capacity utilization μ.

Considering a Leontief production function, labour demand in the modern sector is $\frac{Y}{a_M}$, where a_M is labour productivity. Thus, the share of the labour force employed in the modern sector is given by:

$$E_{Mt} = \frac{Y_t}{a_{Mt}N} \tag{11}$$

where $N > 0$ is the total labour force. We assume that there is no population growth, i.e., that the size of the labour force is constant. This assumption does not influence the conclusions in any major way, and we have a full set of derivations that assumes a fixed non-zero rate of growth of the labour force.

Note that the $(1 - E_M)N$ workers not employed in the modern sector are employed in the traditional sector where they earn a subsistence wage that is equal to their productivity, i.e., there are no profits in the traditional sector. We denote the productivity level in the traditional sector by a_T, with (for simplicity) $\Delta a_T = 0$. Because productivity growth in the modern sector is larger than in the traditional sector, and because the demand policy that we will consider below aims to enlarge the modern sector, we can expect this policy to have a beneficial effect on productivity growth.

3.3. Dynamics of the autonomous demand components

We observe that, in Equation (7), there are two autonomous demand components: government spending and exports. We now turn to how we endogenize these variables, where we draw on the LAS approach and Thirlwall's law. Autonomous exports X depend on the growth of the foreign economy and the income elasticity of exports (we consider only quantity effects so that the price dynamics and the real exchange rate are disregarded, as in the basic Thirlwall approach):

$$\Delta X_t = X_t \varepsilon_{Xt} g_F \tag{12}$$

where $g_F > 0$ is the exogenous growth rate of foreign income and ε_X is the foreign income elasticity of imports. We model this income elasticity as a function of the technology gap, denoted by G, between the Southern economy and the North:

$$\varepsilon_{Xt} = \varepsilon_0(1 - \varepsilon_1 G_t) \tag{13}$$

This formulation is derived from Lavopa (2015, p. 43), who argues that countries that are closer to the technological frontier (i.e., smaller G) tend to produce higher-quality goods, and that high-quality goods tend to have higher elasticities of demand. As the elasticity ε_X varies endogenously with G, it is important to consider what range of values it may take. A value $\varepsilon_X > 1$ seems unreasonable for any steady state because then North's imports from South will eventually rise above its GDP.[2] Because the maximum value of G is 1 (this will be explained in Equation 29 below), $\varepsilon_0(1 - \varepsilon_1) \leq 1$ is necessary but possibly (if $G < 1$) not sufficient to ensure this.

The dynamics of Z_G play a crucial role in the model. In line with, e.g., Alain (2015), we focus on public expenditure as the source of this part of autonomous demand. As we are interested in analysing the role of a demand-led government policy to stimulate the development of the modern sector, we specify autonomous public expenditure to have the aim to bring the employment share of the modern sector to a target level that is denoted by $\bar{E}$. The government adjusts its spending on modern sector output depending on how far away the economy is from this target, increasing (decreasing) expenditure as long as E_M is below (above) the policy target (this is similar to the approach in Nomaler et al., 2021). The policy instrument for this mechanism is the variable ζ (see equation 5):

[2] For example, Senhadji and Montenegro (1999) report estimated (foreign) income elasticities equal to 1.5 on average for a large sample of developing and industrialized countries. Their estimates are for the period 1960 – 1993, which, on the whole is a non-steady-state period of increasing globalization. Devarajan et al. (2023) find that "developing countries' elasticities average around 0.7 for imports and 0.6 for exports" (p. 0).

$$\zeta_t = max[0, \zeta_{t-1} + \iota(\bar{E} - E_{Mt-1})] \quad (14)$$

where $\iota > 0$ is a parameter that specifies the sensitivity of policy. The max(.) operator is necessary in order to avoid negative government spending that would otherwise arise if the employment share of the modern sector is above its target level.[3]

We already specified a tax rate (the traditional sector is not taxed), thus government debt, denoted by Γ, accumulates as

$$\Delta\Gamma_t = (Z_{Gt} - t_t Y_t) \quad (15)$$

We assume that the government matches increased spending by increasing taxes, and to keep things simple, we assume the following rule, which uses total wealth (defined as the capital stock K) as a yardstick for government debt:

$$\Delta t_t = \eta t_t D_t \quad (16)$$

with $D_t \equiv \Gamma_t / K_t$, and $\eta > 0$ a parameter.[4] Note that with this definition of D and equation (15), and using a hat above a variable to denote growth rates[5], we have

$$\Delta D_t = \left(\frac{1}{\widehat{K}_t + 1}\right)\left(\zeta_t - \frac{t_t Y_t}{K_t} - D_t \widehat{K}_t\right) \quad (17)$$

3.4. The external sector

The Southern economy has a trade deficit S equal to

$$S_t = m_t Y_t - X_t \quad (18)$$

As stressed in part of the BOPC literature that we briefly summarized above, the trade deficit accumulates into foreign debt, which we denote by F, so that the following holds:

$$F_t = \sum_{i=1}^{t} S_i \quad (19)$$

$$\Delta F_{t-1} = F_t - F_{t-1} = S_t = m_t Y_t - X_t \quad (20)$$

By substituting Y (Equation 7), this turns into

$$\Delta F_{t-1} = m_t \Omega_t \zeta_t K_t - X_t (1 - m_t \Omega_t) \quad (21)$$

[3] Equations (5), (10) and (14) can be used to show that Z_{Gt} depends only on past income, the past capital stock, and past employment in the modern sector. Hence Z_{Gt} can be seen as semi-autonomous as Caminati and Sordi (2019) use the term.

[4] Expressing D, as well as a number of other variables below, as a fraction of K, is, in the steady state, equivalent to expressing those variables as a fraction of Y, because in the steady state Y/K is constant. We prefer using K instead of Y for mathematical convenience.

[5] I.e., $\hat{V}_t = \Delta V_t / V_t$.

For convenience, we will express exports and foreign debt as a fraction of the capital stock, as in $\chi_t \equiv \frac{X_t}{K_t}$ that expresses exports as a fraction of the capital stock and $B_t \equiv \frac{F_{t-1}}{K_t}$ that expresses foreign debt as a fraction of the capital stock.

Applying the forward difference formula to find the change of B we find

$$\Delta B_t = \frac{1}{1+\widehat{K}_t}\left(\frac{\Delta F_{t-1}}{K_t} - \widehat{K}_t \frac{F_{t-1}}{K_t}\right) = \frac{1}{1+\widehat{K}_t}\left(\frac{\Delta F_{t-1}}{K_t} - \widehat{K}_t B_t\right) \tag{22}$$

Substituting (21) into (22) yields

$$\Delta B_t = \frac{\zeta_t m_t \Omega_t - \chi_t(1-m_t\Omega_t) - B_t\widehat{K}_t}{1+\widehat{K}_t} \tag{23}$$

After we replace the term Ω_t with the explicit multiplier, this turns into

$$\Delta B_t = \frac{1}{1+\widehat{K}_t}\left(\frac{\zeta_t m_t - \chi_t(1-c(1-t_t)-h_t)}{1-c(1-t_t)-h_t+m_t} - B_t\widehat{K}_t\right) \tag{24}$$

With the newly defined variables in terms of the stock of capital, equation (7) can be re-written as

$$Y_t = \frac{K_t(\chi_t+\zeta_t)}{1-c(1-t_t)-h_t+m_t} \tag{25}$$

Also, using equations (12) and (13), we have

$$\Delta \chi_t = \frac{\chi_t}{1+\widehat{K}_t}\left(\varepsilon_0(1-\varepsilon_1 G_t)g_F - \widehat{K}_t\right) \tag{26}$$

Finally, we need an equation that specifies the motion of the propensity to import m. This is where we link to the idea that the BOPC can be seen as a constraint on accumulated trade deficits (see our brief summary of this literature above), and also on the literature that connects imports (of capital goods) to technology flows from the Center/North. We start by defining a parameter $\bar{B}$ that is the maximum value of foreign debt (as a fraction of the capital stock) that South can sustain in the long run. Hence $\bar{B}$ regulates the stringency of the balance of payments constraint that South faces. One specific way in which we may interpret $\bar{B}$ is as North's willingness to take ownership of South's capital stock, or, in other words, to provide foreign direct investment.

In turn, we assume that South is willing to import as much as possible, subject to $\bar{B}$. We model this by a dynamic process that consists of the following equations:

$$\Delta m_t = \varphi(\bar{B} - B_t) \tag{27}$$

$$m_t = min(m_{t-1} + \Delta m_t, \bar{m}) \tag{28}$$

$\varphi > 0$ is a parameter. Thus, as long as South's foreign debt is below the threshold $\bar{B}$, it will keep increasing its propensity to import m_t, but when foreign debt rises above $\bar{B}$, m_t will fall. This dynamic process is subject to an upper threshold value $\bar{m} < 1$ for the propensity to import. We use the harsh bounds $\bar{m}$ and $\bar{B}$ mainly for simplicity. Endogenizing these bounds further to make them more smooth would likely make the derivations of steady states more difficult.

3.5. Productivity and the knowledge gap

To model labour productivity in the modern sector, we follow Lavopa (2015). This means that we introduce an endogenous Southern knowledge stock, as well as an exogenously growing knowledge stock in the North. Labour productivity in each country is directly related to the knowledge stock, as in $a_{MSt} = \alpha_S T_{St}$ and $a_{MNt} = \alpha_N T_{St}$, where T_S and T_N are the knowledge stocks in the South and the North, respectively, a_{MSt} and a_{MNt} are labour productivity in South and North, and α_S and α_N are positive parameters.

The two knowledge stocks define the technology gap between the North and the South that we already used in defining the elasticity of South's exports with regard to North's income (Equation 13). The technology gap is defined as

$$G_t = 1 - \frac{T_{St}}{T_{Nt}} \tag{29}$$

For simplicity, we assume zero population growth (also) in North and that foreign technological knowledge stock (T_N) grows at the same rate as foreign income, i.e., $\hat{T}_N = g_F$, and also that $\alpha_S = \alpha_N$. The latter assumption means that G_t is not only a technology gap but also a productivity gap. For notational simplicity, we will write $a_{Mt} = a_{MSt}$ (as we did before in Equation 11).

The growth rate of the knowledge stock in the Southern economy has an exogenous part, a Kaldor-Verdoorn learning mechanism, (disembodied) knowledge spillovers (catching-up), and embodied knowledge spillovers that are related to imports:

$$\Delta T_{St} = T_{St}\left(\tau_0 + \tau_K \hat{K}_{St} + \tau_G G_t E_{Mt}(1 + \lambda m_t)\right) \tag{30}$$

where τ_0, τ_K, τ_G and λ are parameters that are all positive. τ_0, which is smaller than g_F, is the exogenous component of productivity growth, and $\tau_K \hat{K}$ is the Kaldor-Verdoorn learning effect. In line with the technology gap theory (e.g., Verspagen, 1992), the term $\tau_G G_t E_{Mt}(1 + \lambda m_t)$ captures knowledge spillovers from North. These spillovers depend, first of all, on the size of the gap G_t, which, in this case, represents potential spillovers. E_{Mt} appears in the spillover term to represent the effect of technological congruence (Abramovitz, 1986), which means that South learns more from North if it has a large modern sector (and hence also that the policy to increase E_M will stimulate knowledge spillovers). Finally, $(1 + \lambda m_t)$ represents the embodied spillover channel that relates to the import of intermediate and capital goods, as well as reverse engineering of consumer goods from the North, and the parameter λ regulates the relative importance of this channel. The three main effects (exogenous part, Kaldor-Verdoorn and knowledge spillovers) are additive, and they remain so in the steady-state expressions that we present below.

Box 1. Dual Sector SSM in difference system

$$\Delta h_t = \gamma(u_t - \mu) \tag{8}$$

$$\Delta K_t = h_t Y_t - \delta K_t \tag{10}$$

$$E_{Mt} = \frac{Y_t}{a_{Mt} N} \tag{11}$$

$$\zeta_t = max\left[0, \zeta_{t-1} + \iota(\bar{E} - E_{M_{t-1}})\right] \tag{14}$$

$$\Delta t_t = \eta t_t D_t \tag{16}$$

$$\Delta D_t = \left(\frac{1}{\hat{K}_t + 1}\right)\left(\zeta_t - \frac{t_t Y_t}{K_t} - D_t \hat{K}_t\right) \tag{17}$$

$$\Delta B_t = \frac{1}{1+\hat{K}_t}\left(\frac{\zeta_t m_t - \chi_t(1-c(1-t_t)-h_t)}{1-c(1-t_t)-h_t+m_t} - B_t \hat{K}_t\right) \tag{24}$$

$$Y_t = \frac{K_t(\chi_t + \zeta_t)}{1-c(1-t_t)-h_t+m_t} \tag{25}$$

$$\Delta \chi_t = \frac{\chi_t}{1+\hat{K}_t}\left(\varepsilon_0(1-\varepsilon_1 G_t) g_F - \hat{K}_t\right) \tag{26}$$

$$\Delta m_t = \varphi(\bar{B} - B_t) \tag{27}$$

$$m_t = min(m_{t-1} + \Delta m_t, \bar{m}) \tag{28}$$

$$G_t = 1 - \frac{T_{St}}{T_{Nt}} \tag{29}$$

$$\Delta T_{St} = T_{St}\left(\tau_0 + \tau_K \hat{K}_{St} + \tau_G G_t E_{Mt}(1+\lambda m_t)\right) \tag{30}$$

$$\Delta a_{Mt} = a_{Mt}\frac{\Delta T_{St}}{T_{St}} \tag{31}$$

$$\Delta T_{Nt} = T_{Nt} g_F \tag{32}$$

4. Results

This results in the 15 equations in Box 1 that describe the entire model. In this system, ten variables (u, B, h, χ, ζ, D, E_M, G, m and t) are supposed to converge to a constant level at the steady-state, while the other five (K, T_S, T_N, a_M, Y) are ever-growing variables, but their growth rate converges to a constant level in the steady-state. We derive the expressions for the steady states of the model in Appendix I.

We present four possible types of steady states in a 2×2 configuration in Table 1. All these cases are steady states where only one source of autonomous demand exists. This means that we begin our exposition with cases where the Southern economy is either purely export-based (when policy is absent) or purely policy-based (χ is zero in the steady state[6]). In Appendix I, we investigate the possibility of steady states where both sources of autonomous demand co-exist. However, these steady states seem to be unstable, as indicated by simulation experiments that are documented in Appendix II, and also it is only relevant for a relatively small range of the policy parameter $\bar{E}$, as will be discussed below.

We also limit the discussion here to cases where the outcomes are "feasible" in the sense that the results are economically meaningful. Non-meaningful or non-feasible cases are, for example, cases where the share of employment of the modern sector is negative or larger than 1 or where the steady state value of the elasticity $\varepsilon_X > 1$ (see the discussion of Equation 13 above). Because the model has been specified with South as the technology-follower (e.g., Equation 30), we also deem any cases where the steady-state technology gap is negative as non-feasible.[7]

Which of the four possibilities in Table 1 arises depends on parameter values, including whether or not the government implements a policy ($\bar{E}$). We use a * superscript to denote steady-state values. The rows of the table distinguish between the cases where the Southern government does or does not intervene with a demand-led industrialisation policy, i.e., the parameter $\bar{E}$. The two columns of the table distinguish between the cases in which the steady-state technology gap is smaller than one (i.e., partial catch-up) or where it is equal to one (falling behind).

When the government does not intervene, i.e., with a low or zero value for $\bar{E}$, the bottom row applies. Whether a steady state with $G^* < 1$ exists in the bottom row depends on parameter values, as expressed in the condition in the bottom-left quadrant. Numerical analysis (simulations and numerical evaluation of the Jacobian matrix at the steady state of E_M and G) suggests that if the steady state in the left-bottom quadrant of the table

[6] This means that although exports remain positive and growing, as a fraction of the capital stock (remember $\chi_t \equiv \frac{X_t}{K_t}$) they go to zero because $\hat{X} < \hat{K}$.

[7] G^* in the interval $[-1, 0\rangle$ means that South is the technology leader, and North the follower. But our model contains no specifications where, in such a case, North can benefit from technology spillovers.

exists, it is unstable.[8] A formal stability analysis is difficult because of complications in the steady state expressions. Details of the numerical analysis are documented in Appendix II.

Table 1. Steady-state growth rates of the model

	$G^* < 1$	$G^* = 1$
Purely policy-led growth: $\chi^* = 0$ ($\bar{E}$ high)	$\widehat{K}^* = \hat{a}_M^* = g_F$ With $\varepsilon_0 \leq 1$: arises if $\frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F \bar{B}\frac{\upsilon}{\mu}\right)} < \bar{E}$ With $\varepsilon_0 > 1$: arises if $\frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F \bar{B}\frac{\upsilon}{\mu}\right)} < \bar{E} < \frac{\varepsilon_0\varepsilon_1}{\varepsilon_0-1}\frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F \bar{B}\frac{\upsilon}{\mu}\right)}$	$\widehat{K}^* = \hat{a}_M^* = \frac{\tau_0+\tau_G\bar{E}}{1-\tau_K-\tau_G\lambda\bar{E}\bar{B}\frac{\upsilon}{\mu}}$ Arises if $\frac{\varepsilon_0(1-\varepsilon_1)g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda\left(\varepsilon_0(1-\varepsilon_1)g_F\bar{B}\frac{\upsilon}{\mu}\right)\right)} < \bar{E} \leq$ $\min\left(1, \frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F\bar{B}\frac{\upsilon}{\mu}\right)}\right)$
Export-led growth ($\bar{E}$ low)	$\widehat{K}^* = g_F$ Arises if $g_F(1-\tau_K) - \frac{(\varepsilon_0-1)}{\varepsilon_0\varepsilon_1}\tau_G(1+\lambda\bar{m}) \leq$ $\tau_0 \leq g_F(1-\tau_K)$ and $\varepsilon_0 \geq 1$ and $\varepsilon_0(1-\varepsilon_1) < 1$ Unstable, depending on initial conditions converges to the $G^* = 1$ case or leads to non-feasible results	$\widehat{K}^* = \hat{a}_M^* = \varepsilon_0(1-\varepsilon_1)g_F$

If the conditions in the bottom-left quadrant of the table are met, then a combination of a low initial technology gap and a high initial value of E_M, i.e., a relatively advanced South economy, will lead to non-convergence, i.e., no steady state is observed. When initial

[8] There is one knife-edge parameter set ($\varepsilon_1 = 1$ and $\tau_0 = g_F(1-\tau_K)$) that is on the border of the conditions in the left-bottom quadrant, and which yields a stable steady state with full catching up ($G^* = 0$). This is briefly discussed in Appendix II.

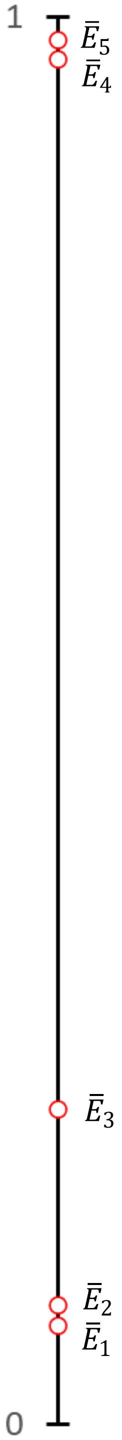
values indicate a less advanced Southern economy (high initial G and low initial E_M), then the South will fall behind (converge to $G^* = 1$) even if a steady state $0 < G^* < 1$ exists. Appendix II provides example simulations of this phenomenon. When conditions for the left-bottom quadrant of the table are not met, similar conclusions arise. For example, when $\varepsilon_0 < 1$, South always falls behind without policy, and when τ_0 is lower than the lower threshold in the bottom-left quadrant, then there is either falling behind or a non-feasible outcome.

Without policy, exports are the only source of autonomous spending in South, and growth will be purely export-led: $\chi^* > 0$. This can be characterized as a Thirlwall state of the Southern economy. The growth rate $\widehat{K}^*$ depends on exports, which in turn depend on foreign income growth and the elasticity parameters ε_0 and ε_1. Note that our specification of imports (Equation 4) dictates that the elasticity of imports with respect to Southern income is exactly unity in the steady state (but not necessarily so in the transient because both m and Y will adjust endogenously outside the steady state). The Southern growth rate (of productivity and capital) adjusts to the growth rate that Is implied by foreign growth and parameters ε_0 and ε_1 to yield a stable and positive value of the employment share of the modern sector, E_M^*.

Even in the Thirlwall state (no policy), South develops a modern sector, i.e., E_M^* is generally > 0, even in the absence of demand policy. But this does not prevent South from falling behind completely, i.e., to converge to $G^* = 1$. Thus, in our model, industrialization may be partial, and is not a guaranteed road to development if we define development as a state of at least partially catching up with the global technological frontier.

In summary, with parameter values and initial states that lead to feasible outcomes, the no-policy state of the South is one in which the steady state is falling behind ($G^* = 1$). We now turn to the question of what changes if the government implements a demand-led industrialization policy $\bar{E} > 0$.

In the top row, i.e., when policy is implemented according to the conditions stated, the foreign economy poses a supply-side restriction (through knowledge spillovers) instead of a demand-side restriction. The demand side of the Southern economy, i.e., autonomous government demand, is now endogenous on the policy target $\bar{E}$, and the knowledge stock, productivity and capital growth in the South adjust to Northern productivity growth to keep the technology and productivity gap stable. The supply side restriction that North poses can be relaxed by higher values of domestic Southern learning capability, in particular τ_0. In summary, while in the Thirlwall (export-led) state, the supply side (capital and productivity) adjusts endogenously to exogenous (and foreign) demand, in the purely policy-led state, the demand side adjusts endogenously to exogenous (and foreign) productivity growth.



$\bar{E}_5 = \left(\frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(\frac{\upsilon}{\mu}\lambda\bar{B}g_F+1\right)}\right)\left(\frac{\varepsilon_0\varepsilon_1}{\varepsilon_0-1}\right)$ is the threshold from Equation (60) and/or (76) above which both the $\chi^* = 0$ with policy steady state and the $\chi^* > 0$ with policy steady state become not feasible

$\bar{E}_4 = \left(\frac{(g_F(1-\tau_K)-\tau_0)}{\tau_G(1+\lambda\bar{m})}\right)\left(\frac{\varepsilon_0\varepsilon_1}{\varepsilon_0-1}\right)$ is the threshold from Equation (77) beyond which the $\chi^* > 0$ with policy steady state becomes feasible

$\bar{E}_3 = \frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F\bar{B}\frac{\upsilon}{\mu}\right)}$ from Equation (59) specifies the threshold above which the policy begins to lead to catching-up

$\bar{E}_2 = \frac{(1-\tau_K)\varepsilon_0(1-\varepsilon_1)g_F-\tau_0}{\tau_G\left(1+\lambda\bar{B}\frac{\upsilon}{\mu}\varepsilon_0(1-\varepsilon_1)g_F\right)}$ from Equation (67) specifies the threshold above which the $\chi^* = 0$ with policy steady state becomes feasible

$\bar{E}_1 = \frac{\varepsilon_0(1-\varepsilon_1)(1-\tau_K)g_F-\tau_0}{\tau_G(1+\lambda\bar{m})}$ from Equation (64) specifies the threshold beyond which policy begins to affect the growth rate, but the $\chi^* = 0$ with policy steady state is not yet feasible

Notes:
Values on the axis represent actual values of the threshold for the parameter set of Experiment 3 in Appendix II, with the exception of $\bar{E}_1$, which has been lowered to visually-distinguish this value from $\bar{E}_2$.

Depending on parameter values, some of the thresholds may not exist, e.g., $\bar{E}_4$and $\bar{E}_5$ do not exist when $\varepsilon_0 < 1$.

Diagram 1. The various thresholds for the policy parameter $\bar{E}$

Diagram 1 shows the intervals of the policy parameter $\bar{E}$ that correspond to different model outcomes. The diagram represents the largest possible set of model outcomes. With different parameter values, e.g., $\varepsilon_0 < 1$ contrary to $\varepsilon_0 > 1$ as in the diagram, $\bar{E}_4$ and $\bar{E}_5$ do not exist. Also, depending on parameter values, $\bar{E}_3$ may not exist.

Below $\bar{E}_1$, policy has no effect because the no-policy (and falling behind) steady state of the bottom-right quadrant of Table 1 leads to $E_M^* > \bar{E}$. In the very narrow interval from $\bar{E}_1$ to $\bar{E}_2$, the policy raises the growth rate of the South, but it is not strong enough to allow the South to reach the steady state of the right-top quadrant of Table 1. As a result, no steady state exists, and the model outcome is a hybrid (i.e., $\chi > 0$ and $\zeta > 0$) between the steady states in the bottom-right and top-right of Table 1.

Between $\bar{E}_2$ and $\bar{E}_3$, the policy leads to the steady state of the top-right of Table 1, i.e., falling behind with $\chi^* = 0$. In the interval from $\bar{E}_3$ to $\bar{E}_4$, the policy leads to catching up and $\chi^* = 0$, as specified in the top-left quadrant of Table 1. Between $\bar{E}_4$ and $\bar{E}_5$, both the steady state of the top-left quadrant of Table 1 and a steady state with $\chi^* > 0$ and policy are possible. Simulations show that in this interval, all initial values that show some kind of convergence lead to catching-up, but convergence to either $\chi^* = 0$ or $\chi^* > 0$ is very slow in these cases. Finally, above $\bar{E}_5$ no steady state is feasible.

A few further details about the steady state are worth noticing. First, we can note that the policy parameter $\bar{E}$ only affects the growth rate $\hat{K}^*$ when $G^* = 1$, and in this case, the growth rate is increasing in $\bar{E}$, i.e., a more ambitious policy yields a higher growth rate. Any policy that is less ambitious than the value E_M^* that would result without government intervention, will not have any effect, and will not require any government spending. Growth will just remain export-led with such an unambitious policy. It can be verified that the borderline case where $\bar{E} = E_M^*$ yields an identical growth rate between the export-led case and the policy-led case.[9] We may, therefore, conclude that a policy that does not take South out of a falling behind situation (i.e., G^* remains 1), will increase the growth rate relative to the export-led state, and hence reduce the tempo in which falling behind takes place. The more ambitious such a policy is, the larger its effect will be.

If government intervention leads to catching up (top-left quadrant of the table), what can be said about the productivity gap in the modern sector, and what does it imply for the corresponding gap in GDP per capita between North and South? For notational simplicity and without loss of generality, we assume a labour participation rate of 1 in the North and in the South. Note that in the South, employment can either be in the stagnant traditional sector or in the modern sector, while in the North, all workers are employed in the modern sector. Then, the GDP per capita in the North is simply equal to Northern labour productivity, while the GDP per capita in the South is equal to $a_{Mt}E_{Mt} +$

[9] Equating the policy-led growth rate with $\bar{E} = E_M^*$ and the export-led growth rate leads to the expression $\bar{m} = \frac{\upsilon \bar{B}}{\mu} \hat{K}^*$ which says that the steady state values m^* must be equal between the two cases (see appendix for the steady state values m^* for $G^* = 1$).

$a_T(1 - E_{Mt})$. The gap in GDP per capita between North and South can then be written in a similar fashion to the knowledge and productivity gap before:

$$Q_t = 1 - \frac{a_{Mt}E_{Mt} + a_T(1-E_{Mt})}{a_{MNt}}$$

where Q is the GDP per capita gap between North and South. Note that in the steady state, the term $\frac{a_T}{a_{MNt}}$ will tend to zero because a_T does not grow and a_{MNt} grows exponentially. Therefore, the steady-state GDP per capita gap is

$$Q^* = 1 - (1 - G^*)E_M^*$$

where we have $E_M^* = \bar{E}$ if the government chooses to intervene. From this expression, it can be seen that as long as $G^* = 1$, $Q^* = 1$, irrespective of any level of industrialization E_M^*. But if the government manages, by means of demand policy, to bring the Southern economy to a state of technological catching up ($G^* < 1$), then the gap in terms of GDP per capita will also be smaller than 1.

Technological catching up is only possible with government demand policy, and as we show in Appendix I, if technological catching up takes place, then the technology gap can be expressed as

$$G^* = \frac{g_F(1-\tau_K) - \tau_0}{\tau_G \bar{E}(1+\lambda m^*)}$$

Note that due to parameter values and/or due to $\bar{E}$ being too low, the righthand side of this expression may be > 1, which would imply that technological catching up is not possible.

By substituting this as well as the steady-state expression $m^* = \frac{v}{\mu}\bar{B}g_F$ (Equation 61 in Appendix I) into the expression for the steady state GDP per capita gap, we find

$$Q^* = 1 - \bar{E} + \frac{g_F(1-\tau_K) - \tau_0}{\tau_G\left(1 + g_F\lambda\bar{B}\frac{v}{\mu}\right)}$$

Seen in this way, the demand policy target $\bar{E}$ directly contributes to lowering Q^* by decreasing the share of the traditional sector $(1 - \bar{E})$. But even if $\bar{E} = 1$, i.e., if the traditional sector vanishes completely, a positive GDP per capita gap will remain as a result of the last term on the righthand side.

This term is solely dependent on supply-side parameters (which may be influenced by supply-side policy, although we consider that to be outside the scope of our paper). The term is decreasing in τ_G, τ_K, and τ_0, which implies that all these "learning-related" parameters tend to lower the GDP per capita gap with North if South manages to catch up. It is increasing in g_F as long as $\tau_K < 1$, which means that if North grows faster, Q^* will grow.

Finally, the denominator of the last term on the righthand side contains the impact of the embodied import spillover channel on Q^*, including the parameters λ and $\bar{B}$. An increase in either of these will lower Q^*. As λ measures the importance of import-embodied spillovers and $\bar{B}$ reflects the stringency of the Southern balance of payments constraint that exists in the global market, the multiplicative term $\lambda\bar{B}$ in the last term of the equation for Q^* reflects that the more important import-embodied spillovers are, the more the stringency of the balance of payments constraint matters for the steady state GDP per capita gap, and vice versa.

5. Discussion

Our model draws on four types of stability mechanisms for the Southern economy: (1) stability in the productive system in terms of capacity utilisation, (2) stability in the labour market in terms of the employment rate in the modern sector, (3) stability of the external sector in terms of the trade balance, and (4) stability in terms of knowledge flows (from North to South) acting on the technology gap.

The stability of capital utilisation is defined by the original SSM (Freitas & Serrano, 2015). Firms have a desired level of capacity utilisation, and they adjust their investment decision (marginal propensity to invest) in order to lead the actual level of capacity utilisation of the economy to its desired level. Without a specific demand-led industrialization policy, the employment stability mechanism tends to lead to low employment shares in the modern sector. As in Nomaler et al. (2021), government policy implements a spending mechanism that answers to differences in effective employment in the modern sector from the policy target rate. In terms of the external sector, foreign debt results from the trade balance. Imports are adjusted as a result of foreign debt accumulation, and the foreign income elasticity of exports is defined by the structural conditions of the economy (Lavopa, 2015; Porcile & Spinola, 2018), given by technology-accumulated knowledge. In terms of the knowledge gap, which is also a productivity gap, adjustment takes place by means of embodied (in imports) and disembodied spillovers.

Not all of these adjustment mechanisms have to be in operation all the time. Depending on which mechanisms work, which depends on parameter values, the model has a different type of equilibrium (steady state), and for some parameter values, no (stable) steady state exists. The different types of possible steady states show that without an active demand policy by the Southern government, the South will never catch up to the North in terms of technological knowledge or GDP per capita. Without demand policy, the economy is export-led in a way that is reminiscent of Thirlwall's law, meaning that the Southern growth rate is determined by foreign income elasticity of exports and the foreign growth rate. A relatively small modern sector will tend to emerge in this state, but technological catch-up is impossible, because the steady state that represents catching-up in the Thirlwall state is unstable.

With a sufficiently ambitious government demand policy, the adjustment mechanism of government demand takes over from exports, i.e., the economy becomes demand policy-led instead of export-led. The development of the modern sector is the mechanism by which catching-up takes place. But it is possible that supply side conditions prohibit catching up, i.e., that no policy is ambitious enough, for example, because learning capacity in South is too low.

The balance of payments constraint also plays a role in whether or not catching up is possible and, if it is possible, how much the South will converge relative to GDP per capita in the North. A softer balance of payments constraint, which is modelled through the extent to which Southern foreign debt is allowed to accumulate from subsequent trade balance deficits, will facilitate imports into the South, which are accompanied by embodied technology spillovers. As a result, a softer (harsher) balance of payments constraint will make catching up easier (harder) and lead to stronger (weaker) convergence.

6. Conclusions

In our theoretical model, which is based on a range of different approaches to structural change and development, government consumption demand can be an important component of industrialisation policy. Although the economy that we model can develop a modern sector without notable government consumption, industrialisation can be further enhanced by a demand-led policy, even with a balanced government budget. Such a policy may potentially bring the economy from a state of falling behind to one of catching up.

While it makes this specific point, our model also shows how various interrelated approaches to the topics of structural change and development that are often applied and analysed in isolation can be usefully applied in a coherent model. Thus, the model has applicability beyond the topic of demand-led policy. For example, while many of the supply-side policies aimed at learning and technology adoption and adaptation are represented by parameters in our model, this side could easily be extended to analyze such policies in an explicit way. In terms of 'pure' theory, our model also shows how the demand-side approach of the supermultiplier can be combined with supply-side dynamics to yield different steady-state regimes in which either the demand- or the supply-side dominates the dynamic path that the economy is on.

However, our approach has been exclusively theoretical. Although we draw on several mechanisms that are well-documented in the literature, such as learning and technology spillovers, we did not attempt any empirical estimation or even calibration of the parameters of the model.

Future empirical work will be necessary to gain insight, for example, into how far government consumption demand can go to stimulate industrialisation. We feel that this is a gap in the literature, which has focused mainly on supply-side policies for industrialisation. Although we do not want to detract from the importance of supply-side policy, we also feel that more attention to the potential role of a demand-led industrialisation policy will be useful. We hope that our model will provide an opportunity to explore this topic, whether it is as a calibrated simulation model or as guidance for quantitative or qualitative analysis of (historical) empirical data on the role of government consumption in industrialising economies.

Acknowledgements

This work was supported by the South African Research Chairs Initiative of the Department of Science and Technology and the National Research Foundation of South Africa (Grant No. 98627). We thank two anonymous reviewers and Thomas Ziesemer for comments on an earlier draft. All views expressed and possible remaining errors remain solely our own responsibility.

References

Abramovitz, M. (1986). Catching Up, Forging Ahead, and Falling Behind. The Journal of Economic History, 46(2), 385-406

Aiginger, K., & Rodrik, D. (2020). Rebirth of industrial policy and an agenda for the twenty-first century. *Journal of Industry, Competition and Trade*, 20(2), 189-207.

Altenburg, T. (2011). Industrial policy in developing countries: overview and lessons from seven country cases (No. 4/2011). Discussion paper.

Andreoni, A., & Chang, H. J. (2019). The political economy of industrial policy: Structural interdependencies, policy alignment and conflict management. *Structural Change and Economic Dynamics*, 48, 136-150.

Andreoni, A., & Tregenna, F. (2020). Escaping the middle-income technology trap: A comparative analysis of industrial policies in China, Brazil and South Africa. *Structural Change and Economic Dynamics*, 54, 324-340.

Barbosa-Filho, N.H. (2001), The balance-of-payments constraint: from balanced trade to sustainable debt, BNL Quarterly Review, no. 219, pp. 381-400.

Blecker, R. A. (2021). New advances and controversies in the framework of balance-of-payments-constrained growth. *Journal of Economic Surveys*. Special Issue.

Blecker, R. A., & Setterfield, M. (2019). Heterodox Macroeconomics. Models of Demand, Distribution and Growth. Cheltenham: Edward Elgar.

Botta, A. (2009). A structuralist North–South model on structural change, economic growth and catching-up. *Structural Change and Economic Dynamics*, *20*(1), 61-73.

Brochier, L., & Silva, A. C. M. e. (2019). A supermultiplier Stock-Flow Consistent model: The "return" of the paradoxes of thrift and costs in the long run? *Cambridge Journal of Economics*, *43*, 413–442.

Bruton, H. J. (1998). A reconsideration of import substitution. *Journal of economic literature*, *36*(2), 903-936.

Caldentey, E. P. (2008). The concept and evolution of the developmental state. *International Journal of Political Economy*, 37(3), 27-53.

Caminati, M., & Sordi, S. (2019). Demand-led growth with endogenous innovation. *Metroeconomica*, 70, 405–422.

Carrasco, C. A., & Tovar-García, E. D. (2021). Trade and growth in developing countries: the role of export composition, import composition and export diversification. *Economic Change and Restructuring*, *54*(4), 919-941.

Chang, H. J. (1994). State, institutions and structural change. *Structural Change and Economic Dynamics*, 5(2), 293-313.

Cimoli, M., Dosi, G. and J. E. Stiglitz (eds) (2009). Industrial policy and development: The political economy of capabilities accumulation, New York, Oxford University Press, 2009.

Cimoli, M., Pereima, J. B., & Porcile, G. (2019). A technology gap interpretation of growth paths in Asia and Latin America. *Research Policy*, 48(1), 125-136.

Cimoli, M., & Porcile, G. (2014). Technology, structural change and BOP-constrained growth: a structuralist toolbox. *Cambridge journal of economics*, 38(1), 215-237.

Davidson, P. (1972). Money and the real world. *The Economic Journal*, 82(325), 101-115.

Deane, P. M. (1979). The first industrial revolution. *Cambridge University Press*.

Deleidi, M., & Mazzucato, M. (2019). Putting Austerity to Bed: Technical Progress, Aggregate Demand and the Supermultiplier. *Review of Political Economy*, *31(3)*, 315-335.

Deleidi, M., & Mazzucato, M. (2021). Directed innovation policies and the supermultiplier: An empirical assessment of mission-oriented policies in the US economy. *Research Policy*, 50(2), 104151.

Devarajan, S., Go, D.S. and S. Robinson (2023), Trade elasticities in Aggregate Models. Estimates for 191 Countries, Policy Research Working Paper 10490, Washington DC: World Bank.

de Paula, L. F., & Jabbour, E. (2020). The Chinese Catching-Up: A Developmentalist Approach. *Journal of Economic Issues*, *54*(3), 855-875.

Dosi, G., Pavitt, K. and Soete, L. 1990. The Economics of Technical Change and International Trade, Brighton, Wheatsheaf.

ECLAC. 1955. Estudio económico de América Latina, 1954, Santiago, ECLAC.

Fagerberg, J. 1994. Technology and International Differences in Growth Rates, Journal of Economic Literature, XXXII (3): 1147-1175.

Fagerberg, J., & Godinho, M. M. (2005). *Innovation and catching-up*. Chapter 19 in J. Fagerberg, D. C. Mowery and R. Nelson (eds.). *The Oxford Handbook of Innovation*, New York, OUP, pp. 514–542.

New York, OUP, pp. 514–542

Fajnzylber, F. (1990). *Industrialization in Latin America: from the black box" to the" empty box": a comparison of contemporary industrialization patterns"*. Cuadernos de la CEPAL no. 60, CEPAL, Santiago de Chile.

Felipe, J., Abdon, A., & Kumar, U. (2012). Tracking the middle-income trap: What is it, who is in it, and why? Levy Economics Institute, Working Paper No. 715, Annandale-on-Hudson, NY.

Freitas, F., & Christianes, R. (2020). A baseline supermultiplier model for the analysis of fiscal policy and government debt. *Review of Keynesian Economics*, 8(3), 313-338.

Freitas, F., & Serrano, F. (2015). Growth Rate and Level Effects, the Stability of the Adjustment of Capacity to Demand and the Sraffian Supermultiplier. *Review of Political Economy*, *27*, 258–281.

Gouvêa, R. R., & Lima, G. T. (2010). Structural change, balance-of-payments constraint, and economic growth: evidence from the multisectoral Thirlwall's law. *Journal of Post Keynesian Economics*, *33*(1), 169-204.

Grossman, G. M., & Helpman, E. (1991). Trade, knowledge spillovers, and growth. *European economic review*, *35*(2-3), 517-526.

Hallonsten, J. S. & T. Ziesemer, 2016, A semi-endogenous growth model for developing countries with public factors, imported capital goods, and limited export demand, UNU-MERIT Working Paper 2016-004.

Hartwell, R. M. (2017). The industrial revolution and economic growth (Vol. 4). Taylor & Francis.

Hirschman, A. O. (1968). The political economy of import-substituting industrialization in Latin America. *The Quarterly Journal of Economics*, *82*(1), 1-32.

Kaldor, N. (1957), A Model of Economic Growth. *The Economic Journal*, 67, pp. 591-624.

Kögel, T., & Prskawetz, A. (2001). Agricultural productivity growth and escape from the Malthusian trap. *Journal of economic growth*, 6(4), 337-357.

Landesmann, M. A., & Stöllinger, R. (2019). Structural change, trade and global production networks: An 'appropriate industrial policy'for peripheral and catching-up economies. *Structural Change and Economic Dynamics*, 48, 7-23.

Lavoie, M. (2016). Convergence Towards the Normal Rate of Capacity Utilization in Neo-Kaleckian Models: The Role of Non-Capacity Creating Autonomous Expenditures. *Metroeconomica*, 67, 172–201.

Lavopa, A., & Szirmai, A. (2018). Structural modernisation and development traps. An empirical approach. *World Development*, 112, 59-73.

Lavopa, A. M. (2015). Structural transformation and economic development: can development traps be avoided? Doctoral dissertation, Maastricht University.

Lee, J. W. (1995). Capital goods imports and long-run growth. *Journal of development economics*, *48*(1), 91-110.

Lee, K. (2019). *The art of economic catch-up: Barriers, detours and leapfrogging in innovation systems*. Cambridge University Press.

Lee, K., & Malerba, F. (2017). Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems. *Research Policy*, 46(2), 338-351.

Lewis, W. A. (1954). Economic development with unlimited supplies of labour. *The Manchester School*, 22(2), 139-191.

Lin, J. Y. (2017). Industrial policies for avoiding the middle-income trap: a new structural economics perspective. *Journal of Chinese Economic and Business Studies*, 15(1), 5-18.

Mazzucato, M. (2011). *The entrepreneurial state*. Soundings, 49(49), 131-142.

Mazzucato, M. (2018). Mission-oriented innovation policies: Challenges and opportunities. *Industrial and Corporate Change*, 27(5), 803-815.

Marx, B., Stoker, T., & Suri, T. (2013). The economics of slums in the developing world. *Journal of Economic Perspectives*, 27(4), 187-210.

McCombie, J.S.L. and A.P. Thirlwall (1997), "Economic growth and the balance of payments constraint revisited", in P. Arestis, G. Palma and M. Sawyer eds, Markets, Unemployment and Economic Policy: Essays in Honour of Geoffrey Harcourt, vol. 2, Routledge, London, pp. 498-511.

McCombie, J., & Thirlwall, T. (Eds.). (2004). *Essays on balance of payments constrained growth: Theory and evidence*. London & New York: Routledge.

McCombie, J. S. (2012). Criticisms and defences of the balance of payments constrained growth model: Some old, some new. In *Models of Balance of Payments Constrained Growth: History, Theory and Empirical Evidence* (pp. 50-82). London: Palgrave Macmillan UK.

Moreno-Brid, J.C. (1998), On capital flows and the balance-of-payments-constrained growth model, Journal of Post Keynesian Economics, vol. 21, pp. 283-98.

Nah, W. J., & Lavoie, M. (2017). Long-run convergence in a neo-Kaleckian open-economy model with autonomous export growth. *Journal of Post Keynesian Economics*, 40, 223–238.

Nelson, R. R., & Pack, H. (1999). The Asian miracle and modern growth theory. *Economic Journal*, 109, 416-436.

Nomaler, O., Spinola, D., & Verspagen, B. (2021). R&D-based economic growth in a supermultiplier model. *Structural Change and Economic Dynamics*, 59, 1-19.

Ocampo, J. A., & Porcile, G. (2021). Latin American industrial policies: A comparative perspective. In *The Oxford Handbook of Industrial Policy*, edited by Oqubay, A., Cramer, C., Chang, H.-J., & Kozul-Wright, R. Oxford: Oxfod University Press.

Pinto, A. (1976). La CEPAL y el problema del progreso técnico. *El Trimestre Económico*, *43*(170 (2), 267-284.

Porcile, G., & Spinola, D. (2018). Natural, effective and BOP-constrained rates of growth: Adjustment mechanisms and closure equations. *PSL Quarterly Review*, 71(285), 139-160.

Porcile, G., & Yajima, G. T. (2021). New Structuralism and the balance-of-payments constraint. In *Thirlwall's Law at 40* (pp. 91-110). Edward Elgar Publishing.

Porcile, G. (2021), Latin American Structuralism and Noe-structuralism, in: Foster-McGregor, N., Alcorta, L., Szirmai, A. and B. verspagen (eds.), New Perspectives on Structural Change, Oxford: Oxford University Press, pp. 50-71.

Prebisch, R. (1950). The economic development of Latin America and its principal problems. Economic Commission for Latin America. New York: United Nations Department of Economic Affairs.

Rivera-Batiz, L. A., & Romer, P. M. (1991). Economic integration and endogenous growth. *The Quarterly Journal of Economics*, *106*(2), 531-555.

Rodríguez, O. 2007. El estructuralismo Latinoamericano, México, Siglo XXI

Rodrik, D. (2016). Premature deindustrialization. *Journal of Economic Growth*, 21(1), 1-33.

Sasaki, H. (2021). Thirlwall's law, uneven development, and income distribution. *Metroeconomica*, 72(3), 592-611.

Senhadji, A.S. & C.E. Montenegro, 1999, Time Series Analysis of Export Demand Equations: A Cross-Country Analysis, *IMF Staff Papers*, Vol. 46, pp. 259-73.

Sunkel, O. (1978). La dependencia y la heterogeneidad estructural. *El trimestre económico*, *45*(177) (1), 3-20.

Szirmai, A. (2012). Industrialisation as an engine of growth in developing countries, 1950–2005. *Structural Change and Economic Dynamics*, 23(4), 406-420.

Thirlwall, A. P. (1979). The balance of payments constraint as an explanation of international growth rate differences. *BNL Quarterly Review*, 32(128), 45-53.

Thirlwall, A. P., & Hussain, M. N. (1982). The balance of payments constraint, capital flows and growth rate differences between developing countries. *Oxford economic papers*, 34(3), 498-510.

Tregenna, F. (2016). Deindustrialization and premature deindustrialization. In Elgar *Handbook of Alternative Theories of Economic Development*, edited by Ghosh, J., Kattel, R., & Reinert, E. 710-728. London: Edward Elgar.

Verspagen, B. (1992). Uneven growth between interdependent economies: An evolutionary view on technology gaps, trade and growth.

Wade, R. H. (2018). The developmental state: dead or alive?. *Development and Change*, 49(2), 518-546.

Ziesemer, Thomas, 1995, Growth with imported capital goods, limited export demand and foreign debt, Journal of Macroeconomics, 17(1): 31-53

Ziesemer, T. & J. S. Hallonsten, 2019, A semi-endogenous growth model for developing countries with public factors, imported capital goods, and limited export demand, Journal of Applied Economics.

Appendix I. Derivation of the steady states

The core of the model is formed by a subsystem of two dynamic equations. Depending on the sources of autonomous demand that drive the economy, these two equations solve for distinct sets of variables. If the economy is purely export-led, the two equations solve for G and E_M. If the economy is purely policy-led, government demand is the source of autonomous demand, and the two equations solve for G and $\widehat{K}_t$. These are the two main cases that we consider in the main text. There is a third case where the economy is both export-led and policy-led, and exports and government demand co-exist as sources of autonomous demand. In this case, the two core equations solve for G and the import propensity m. We cover this steady state at the end of this appendix, but the simulations in Appendix II suggest that it is not stable.

The first equation of the core subsystem asks for a stable technology gap G, and is obtained by differentiating Equation (29) with respect to time and setting the result to zero:

$$\Delta G_t = -\frac{T_{St}}{T_{Nt}}\left(\widehat{T}_{St} - \widehat{T}_{Nt}\right)\frac{1}{1+\widehat{T}_{Nt}} = (1 - G_t)\left(\widehat{T}_{Nt} - \widehat{T}_{St}\right)\frac{1}{1+\widehat{T}_{Nt}} = 0 \tag{33}$$

The other equation of the core subsystem uses the definition $E_{Mt} = \frac{Y_t}{a_{Mt}N}$ (Equation 11), the assumption of a constant labour force and the definition $\frac{Y_t}{K_t} = \frac{\mu}{v}$, and says that in order to maintain a constant (non-zero) value of E_M, we need

$$\widehat{K}_t = \hat{a}_{Mt} \tag{34}$$

Equation (33) can be solved in two ways: either $G^* = 1$ (we use a * superscript to denote steady-state values), which corresponds to complete falling behind of the South in terms of knowledge and productivity, or $\widehat{T}_{St} = \widehat{T}_{Nt} = g_F$, i.e., that the knowledge stocks (and hence productivity) in North and South grow at an equal rate, which is the exogenous rate in North, g_F (Equation 32). The later solution implies that the rate of knowledge growth in South (Equation 30) needs to adjust to become equal to g_F, and this allows catching up ($G^* < 1$). In case $G^* = 1$, such adjustment is not necessary, and knowledge (productivity) in South will grow at a slower rate than g_F. These two ways of solving Equation (33) give rise to a dichotomy of steady states: those with catching up ($G^* < 1$) and those with falling behind ($G^* = 1$).

There are also two possibilities for how Equation (34) will hold, i.e., how a stable value of E_M is obtained (this is covered in Equation 36 below). If the government decides not to intervene, $\widehat{K}$ will depend on the export variable χ, so that both the lefthand side (through the elasticity of exports) and the righthand side (through spillovers) depend on the technology gap G. If, on the other hand, the government does (successfully) intervene and sets a value $\bar{E}$ that is higher than what would be achieved without government intervention, then the value $\bar{E}$ is maintained by government demand influencing output (and capital formation $\widehat{K}$) through the supermultiplier. This leads to a second dichotomy of steady states: those with and without government policy. The two dichotomies combined lead to the 2×2 configuration of Table 1 in the main text.

Whether or not the government intervenes with a demand policy has important consequences beyond the core subsystem. If the government does not intervene (or sets a target $\bar{E}$ below E_M^* that would result without intervention), then Equation (14) shows that the spending variable ζ will converge to zero, i.e., $\zeta^* = 0$. Moreover, equation (16) shows that irrespective of the value of ζ, the government debt variable D must have a steady-state value of zero for the tax rate t to be in a steady state. Then, with $\zeta^* = 0$ and $D^* = 0$, Equation (17) also implies $t^* = 0$. In summary, as long as $\bar{E} < E_M^*$, the government does not spend and does not tax, and consequently has no debt.

There is a further consequence of the absence of government intervention ($\bar{E} < E_M^*$), which can be seen when we set equation (24) to zero to find a steady state for B. With $\zeta^* = 0$, and hence $t^* = 0$, this leads to

$$\Delta B_t = -\frac{1}{1+\widehat{K}_t}\left(\frac{\chi_t(1-c-h_t)}{1-c-h_t+m_t} + B_t\widehat{K}_t\right) = 0 \Rightarrow B^* < 0 \tag{35}$$

With B^* negative, South accumulates an external surplus, not a deficit, and because the parameter $\bar{B} > 0$, Equation (27) then says that in the steady state, m will keep increasing until it reaches the maximum level $\bar{m}$ that Equation (28) imposes. Thus, without government intervention, $m^* = \bar{m}$.

In what follows, we start by analysing the case where, in the steady state, there is only one source of autonomous demand, i.e., either government demand or exports. This leads to the steady states that are discussed in the main text. After we derive these steady states, the last section of this appendix also considers the possibility of a steady state where the two sources of autonomous demand co-exist.

To see how the absence or presence of autonomous export demand matters, consider how a steady state value of the export variable χ may arise. For this, we set Equation (26) to zero, which yields two options:

$$\widehat{K}_t = \varepsilon_0(1 - \varepsilon_1 G_t)g_F \text{ or } \chi^* = 0 \tag{36}$$

If autonomous export demand exists in the steady state, i.e., if $\chi^* > 0$, then a steady state value χ^* arises through the adjustment of the growth rate of the South ($\widehat{K}$) to external demand, $\varepsilon_0(1 - \varepsilon_1 G)g_F$. As was already noted in the brief discussion of Equation (13), in this export-driven state of the Southern economy, only steady states where $\varepsilon_0(1 - \varepsilon_1 G^*) \leq 1$ are meaningful because otherwise North's imports from the South would grow faster than its GDP. Adjustment of Southern growth to foreign demand does not take place if autonomous export demand is absent ($\chi^* = 0$), but in this case, there must be autonomous government demand.

We now proceed to look at the case of a purely export-led Southern economy, i.e., the absence of any government intervention.

Export-led growth (no government intervention) with $G^* < 1$

We start by looking at the non-government steady state where South manages to partially catch up in terms of knowledge and productivity ($G^* < 1$). As there is no government intervention, and as explained above, the following must hold to reach a steady state $\chi^* > 0$:

$$\widehat{K}_t = \varepsilon_0(1 - \varepsilon_1 G_t)g_F \tag{37}$$

Because we look for a steady state where $G^* < 1$, we need $\widehat{T}_{St} = \widehat{T}_{Nt}$ in Equation (33). As already noted before (and also writing equations 31 and 32 in rate of change terms), this leads to

$$\hat{a}_{Mt} = \widehat{T}_{St} = g_F \tag{38}$$

We can substitute Equations (30) and (37) and also use $m^* = \overline{m}$ (because there is no government intervention) to obtain

$$\tau_0 + \tau_K \varepsilon_0(1 - \varepsilon_1 G_t)g_F + \tau_G G_t E_{Mt}(1 + \lambda\overline{m}) = g_F \tag{39}$$

Equation (34) is the requirement for a steady state of E_M, and under the conditions that we are currently considering, we can substitute the lefthand side of Equation (39) for $\hat{a}_{Mt}$ and Equation (37) for $\widehat{K}_t$, which yields

$$\varepsilon_0(1 - \varepsilon_1 G_t)g_F = \tau_0 + \tau_K \varepsilon_0(1 - \varepsilon_1 G_t)g_F + \tau_G G_t E_{Mt}(1 + \lambda\overline{m}) \tag{40}$$

Equations (39) and (40) form our core subsystem, and they contain only G and E_M. We can solve for the following steady-state values of these variables:

$$G^* = \frac{(\varepsilon_0 - 1)}{\varepsilon_0 \varepsilon_1} \tag{41}$$

$$E_M^* = \frac{(g_F(1 - \tau_K) - \tau_0)\varepsilon_0 \varepsilon_1}{\tau_G(\varepsilon_0 - 1)(1 + \lambda\overline{m})} \tag{42}$$

With Equations (41) and (42) satisfied, the steady-state growth rate of the Southern economy becomes

$$\widehat{K}^* = g_F \tag{43}$$

Substitution of Equation (41) into (13) yields $\varepsilon_X^* = 1$. This means that in the steady state where catching up arises without policy, the export elasticity of the South with respect to Northern income needs to converge to 1.

Because of the way that the model is built (essentially North's growth rate is exogenous, and growth in the South depends on South's status as a technology follower), only steady-state values G^* and E_M^* in the interval [0,1] are economically meaningful. Several conditions need to be fulfilled to make this happen.

Equation (41) shows that $G^* \geq 0$ requires $\varepsilon_0 \geq 1$. Equation (42) further specifies that $\varepsilon_0 = 1$ (which leads to $G^* = 0$, i.e., complete catching-up) is a borderline special case (that we investigate with simulations in Appendix II), as E_M^* becomes indeterminate with this value. The indeterminacy disappears when $\varepsilon_0 > 1$. For $G^* < 1$, we further need $\varepsilon_0(\varepsilon_1 - 1) < 1$.

The conditions for $E_M^* \in [0,1]$ can be expressed in terms of the exogenous learning rate τ_0. Specifically, we need

$$g_F(1-\tau_K) - \frac{(\varepsilon_0 - 1)}{\varepsilon_0\varepsilon_1}\tau_G(1+\lambda\bar{m}) \leq \tau_0 \leq g_F(1-\tau_K)$$

Note that, depending on other parameter values, it is possible that $\tau_0 = 0$ satisfies this condition.

Export-led growth (no government intervention) with $G^* = 1$

We now consider the alternative solution to Equation (33), which is $G = 1$, while maintaining the assumption of no government intervention. Then Equation (37) still holds, but we must substitute $G^* = 1$:

$$\widehat{K}^* = \varepsilon_0(1-\varepsilon_1)g_F \tag{44}$$

Note that, as already stressed before, only parameter values $\varepsilon_0(1-\varepsilon_1) \leq 1$ lead to a meaningful steady state.

Equation (39) no longer holds because we do not require $\hat{T}_{St} = \hat{T}_{Nt}$, but Equation (40) does apply in order to obtain a stable value E_M^*. We must then again substitute $G^* = 1$:

$$\varepsilon_0(1-\varepsilon_1)g_F = \tau_0 + \tau_K\varepsilon_0(1-\varepsilon_1)g_F + \tau_G E_{Mt}(1+\lambda\bar{m}) \tag{45}$$

which immediately yields

$$E_M^* = \frac{\varepsilon_0(1-\varepsilon_1)(1-\tau_K)g_F - \tau_0}{\tau_G(1+\lambda\bar{m})} \tag{46}$$

Next, in the steady state, Equation (10) requires $\widehat{K}^* = h_t \frac{Y_t}{K_t} - \delta$, and since $\frac{Y_t}{K_t} = \frac{\mu}{v}$, we obtain

$$h^* = \left(\widehat{K}^* + \delta\right) \frac{v}{\mu} = \left(\varepsilon_0(1 - \varepsilon_1) g_F + \delta\right) \frac{v}{\mu} \tag{47}$$

Equation (8) immediately yields

$$u^* = \mu \tag{48}$$

This leaves the steady-state values B^* and χ^* to be determined. Setting Equation (24) to zero yields

$$\chi_t = -B_t \widehat{K}^* \frac{1 - c - h^* + \overline{m}}{1 - c - h^*} \tag{49}$$

Box A1. Steady state values for export-led growth (no government intervention) with $G^* = 1$

$$u^* = \mu$$
$$h^* = \frac{v}{\mu}\left(\widehat{K}^* + \delta\right) = \frac{v}{\mu}\left(\varepsilon_0(1 - \varepsilon_1) g_F + \delta\right)$$
$$\widehat{Y}^* = \widehat{K}^* = \widehat{a}_M^* = \varepsilon_0(1 - \varepsilon_1) g_F$$
$$E_M^* = \frac{(1 - \tau_K)\varepsilon_0(1 - \varepsilon_1) g_F - \tau_0}{\tau_G(1 + \lambda \overline{m})}$$
$$\zeta^* = 0$$
$$t^* = 0$$
$$D^* = 0$$
$$B^* = -\frac{\mu(1 - c - h^*)}{v \widehat{K}^*}$$
$$\chi^* = \frac{\mu}{v}(1 - c - h^* + \overline{m})$$
$$m^* = \overline{m}$$
$$G^* = 1$$

Substitution of Equation (20) into (22), together with $\frac{Y_t}{K_t} = \frac{\mu}{v}$ and $m^* = \overline{m}$, yields

$$\Delta B_t = \frac{1}{1 + \widehat{K}_t}\left(\overline{m}\frac{\mu}{v} - \chi_t - \widehat{K}^* B_t\right) \tag{50}$$

Setting this to zero results in

$$\chi_t = \bar{m}\frac{\mu}{\upsilon} - \hat{K}^* B_t \tag{51}$$

Finally, equating (49) and (51), we find

$$B^* = -\frac{\mu}{\upsilon}\left(\frac{1-c-h^*}{\hat{K}^*}\right) \tag{52}$$

Substituting this back into Equation (51) yields

$$\chi^* = (1 - c - h^* + \bar{m})\frac{\mu}{\upsilon} \tag{53}$$

Box A1 collects all steady-state values for the case of export-led growth with $G^* = 1$.

Policy-led growth with $G^* < 1$

For the policy-led case, we must notice that our derivations so far were based on $\hat{K}_t = \varepsilon_0(1 - \varepsilon_1 G_t)g_F$ (Equation 37), which is one of the alternative solutions to Equation (26). Together with other equations, $\hat{K}_t = \varepsilon_0(1 - \varepsilon_1 G_t)g_F$ led to the alternative steady-state values E_M^* that are specified in Equations (42) and (46). Because, in first instance, we limit the case of government intervention to $\chi^* = 0$, i.e., the South is purely government-led, Equations (37), (42) and (46) no longer hold. Instead, we will use the option $\chi^* = 0$ from Equation (36).

This immediately changes the working of the foreign deficit variable B, for which Equation (27) now dictates $B^* = \bar{B}$. Accordingly, $m^* = \bar{m}$ will not hold anymore. To find the new steady-state value m^*, we again substitute Equation (20) into (22), this time with $\chi^* = 0$ and $B^* = \bar{B}$, again use $\frac{Y_t}{K_t} = \frac{\mu}{\upsilon}$, and set the result to zero to obtain

$$m_t = \hat{K}_t \frac{\upsilon\bar{B}}{\mu} \tag{54}$$

This leaves the steady state growth rate $\hat{K}^*$ to be determined to find m^*. To find this, we use Equation (54) to write alternatives to Equations (39) and (40):

$$\tau_0 + \tau_K\hat{K}_t + \tau_G G_t \bar{E}\left(1 + \lambda\hat{K}_t\bar{B}\frac{\upsilon}{\mu}\right) = g_F \tag{55}$$

$$\hat{K}_t = \tau_0 + \tau_K\hat{K}_t + \tau_G G_t \bar{E}\left(1 + \lambda\hat{K}_t\bar{B}\frac{\upsilon}{\mu}\right) \tag{56}$$

The core subsystem is now formed by these two equations, which now contain the variables $\hat{K}_t$ and G_t (instead of E_{Mt} and G_t when government intervention was absent). We can solve for the steady-state solutions.

$$\widehat{K}^{*} = g_F \tag{57}$$

$$G^{*} = \frac{g_F(1-\tau_K)-\tau_0}{\tau_G \bar{E}\left(1+\lambda g_F \bar{B}\frac{\upsilon}{\mu}\right)} \tag{58}$$

For the righthand side of this last equation to be smaller than 1, i.e., $G^{*} < 1$, the policy needs to be sufficiently ambitious because the following is a requirement:

$$\bar{E} > \frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F \bar{B}\frac{\upsilon}{\mu}\right)} \tag{59}$$

If the righthand side of condition (59) is larger than 1, then there is no policy that can achieve catching up ($G^{*} < 1$).

Because when introducing Equation (13), we required the export elasticity (with respect to foreign income) $\varepsilon_{Xt} \leq 1$, there is an additional restriction on the policy, which states that with the steady stage gap in (58), the elasticity cannot exceed one. This implies

$$\bar{E} \leq \left(\frac{\varepsilon_0 \varepsilon_1}{\varepsilon_0 - 1}\right)\left(\frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F \bar{B}\frac{\upsilon}{\mu}\right)}\right) \tag{60}$$

Note that this last condition only holds in case $\varepsilon_0 > 1$. If $\varepsilon_0 < 1$, no condition additional to (59) applies. It is also interesting to note that the necessary condition for the convergence of χ^{*} to zero, i.e., $\widehat{K}_t = g_F > \varepsilon_0(1-\varepsilon_1 G_t)g_F$, together with equation 58) will exactly imply inequality (60).

The steady-state value m^{*} can easily be found by substituting Equation (57) into (54):

$$m^{*} = \frac{\upsilon \bar{B}}{\mu} g_F \tag{61}$$

Because m^{*} cannot exceed $\bar{m}$, and with $\varepsilon_0(1-\varepsilon_1) \leq 1$, which means that the export elasticity ε_X is "not very large", the condition of Equation (59) also ensures that the policy $\bar{E}$ exceeds the steady state E_M^{*} that results without policy (Equation 46).

Box A2. Steady state values for policy-led growth with $G^* < 1$

$$u^* = \mu$$

$$h^* = \frac{v}{\mu}\left(\widehat{K}^* + \delta\right) = \frac{v}{\mu}(g_F + \delta)$$

$$\widehat{K}^* = \hat{a}_M^* = g_F$$

$$E_M^* = \bar{E}$$

$$\zeta^* = t^* \frac{\mu}{v} = \frac{\mu}{v} - \frac{(1-\bar{B})g_F + \delta}{1-c}$$

$$t^* = 1 - \frac{h^* - m^*}{1-c} = 1 - \frac{v}{\mu(1-c)}\left((1-\bar{B})g_F + \delta\right)$$

$$D^* = 0$$

$$B^* = \bar{B}$$

$$\chi^* = 0$$

$$m^* = \frac{v}{\mu}\bar{B}g_F$$

$$G^* = \frac{g_F(1-\tau_K) - \tau_0}{\tau_G \bar{E}(1 + \lambda m^*)} = \frac{g_F(1-\tau_K) - \tau_0}{\tau_G \bar{E}\left(1 + \lambda g_F \bar{B}\frac{v}{\mu}\right)}$$

The steady-state value h^* doesn't change as a function of $\widehat{K}^*$, and also u^* doesn't change. This leaves the steady state values for the two government-related variables, ζ^* and t^* to be determined.

Setting Equation (17) to zero, with $D^* = 0$ and $\frac{Y_t}{K_t} = \frac{\mu}{v}$ yields $\zeta_t = t_t \frac{\mu}{v}$ and Equation (25) with $\chi^* = 0$ can be rewritten to obtain $\frac{\mu}{v} = \frac{\zeta_t}{1-c(1-t_t)-h^*+m^*} \Rightarrow \frac{\mu}{v}(1 - c(1-t_t) - h^* + m^*) = \zeta_t$, and by equating these two expressions, we obtain

$$t^* = 1 - \frac{h^* - m^*}{1-c} \qquad (62)$$

and by substituting back

$$\zeta^* = t^* \frac{\mu}{v}\left(1 - \frac{h^* - m^*}{1-c}\right) \qquad (63)$$

Box A2 collects all steady-state values for demand policy-led growth with $G^* < 1$.

Policy-led growth with $G^* = 1$

If parameter values are such that the righthand side of the condition in Equation (59) yields a value > 1, or $\bar{E}$ is not high enough to satisfy this condition, then for the policy to have any effect, the policy parameter $\bar{E}$ must at least exceed the value in Equation (46), i.e., the policy needs to be sufficiently ambitious to "improve" on the no-policy steady state E_M^* and its associated growth rate in Equation (44). All these conditions together lead to the following parameter restriction for the case of policy-led growth with $G^* = 1$ to happen:

$$\frac{\varepsilon_0(1-\varepsilon_1)(1-\tau_K)g_F-\tau_0}{\tau_G(1+\lambda\bar{m})} < \bar{E} \leq \min\left(1, \frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(1+\lambda g_F \bar{B}\frac{v}{\mu}\right)}\right) \tag{64}$$

Note that the leftmost term in this condition stems from Equation (46), and the rightmost term stems from Equation (59). The minimum operator in the rightmost expression results since the inequality in Equation (59) can fail because either its righthand side exceeds 1 (which makes any policy insufficient to meet the inequality), or the policy $\bar{E}$ may not be ambitious enough.

With this condition satisfied, Equation (51), which states $\hat{T}_{St} = \hat{T}_{Nt}$, no longer holds because the technology gap will converge to $G^* = 1$ in the steady state. This is the alternative solution for Equation (33). Instead of the growth rate of the Southern knowledge stock being equal to that in North, Southern knowledge now grows perpetually slower than North. Equation (56), on the other hand, still holds, and we can substitute $G = 1$

$$\hat{K}_t = \tau_0 + \tau_K \hat{K}_t + \tau_G \bar{E}\left(1 + \lambda \hat{K}_t \bar{B}\frac{v}{\mu}\right) \tag{65}$$

This now readily solves for the steady-state growth rate

$$\hat{K}^* = \frac{\tau_0 + \tau_G \bar{E}}{1-\tau_K-\tau_G\lambda\bar{E}\bar{B}\frac{v}{\mu}} \tag{66}$$

For this growth rate to be equal to or larger than the no-policy growth rate of Equation (44), an additional constraint applies:

$$\bar{E} \geq \frac{(1-\tau_K)\varepsilon_0(1-\varepsilon_1)g_F-\tau_0}{\tau_G\left(1+\lambda\bar{B}\frac{v}{\mu}\varepsilon_0(1-\varepsilon_1)g_F\right)} \tag{67}$$

As long as the threshold of (67) is not met, the policy steady-state growth rate of Equation (66) is not attainable. This means that if the policy parameter $\bar{E}$ exceeds $\frac{\varepsilon_0(1-\varepsilon_1)(1-\tau_K)g_F-\tau_0}{\tau_G(1+\lambda\bar{m})}$, which is the left-hand side of Equation (64), but is still below $\frac{(1-\tau_K)\varepsilon_0(1-\varepsilon_1)g_F-\tau_0}{\tau_G\left(1+\lambda\bar{B}\frac{v}{\mu}\varepsilon_0(1-\varepsilon_1)g_F\right)}$ (Equation 67), neither of the two steady-state growth rates applies, and the Southern economy shows a hybrid form of the no-policy and the policy steady-state growth rates (both with $G^* = 1$).

The derivation of the other variables does not change relative to the case of policy-led growth with $G^* < 1$, although we have to leave some of these steady-state values as functions of $\widehat{K}^*$. Box A3 collects all steady-state values.

Box A3. Steady-state values policy-led growth with $G^* = 1$

$$u^* = \mu$$

$$h^* = \left(\widehat{K}^* + \delta\right)\frac{\upsilon}{\mu}$$

$$\widehat{K}^* = \hat{a}_M^* = \frac{\tau_0 + \tau_G \bar{E}}{1 - \tau_K - \tau_G \lambda \bar{E}\bar{B}\frac{\upsilon}{\mu}}$$

$$E_M^* = \bar{E}$$

$$\zeta^* = t^* \frac{\mu}{\upsilon}$$

$$t^* = 1 - \frac{h^* - m^*}{1 - c} = 1 - \frac{\upsilon}{\mu(1-c)}\left((1 - \bar{B})\widehat{K}^* + \delta\right)$$

$$D^* = 0$$

$$B^* = \bar{B}$$

$$\chi^* = 0$$

$$m^* = \frac{\upsilon \bar{B}}{\mu}\widehat{K}^*$$

$$G^* = 1$$

A steady state with $\chi^* > 0$, government intervention and $G^* < 1$

We now proceed to investigate the possibility of a steady state where government demand and export demand co-exist. Because $\chi^* > 0$, Equation (36) implies $\widehat{K}_t = \varepsilon_0(1 - \varepsilon_1 G_t)g_F$, which is also Equation (37). We start by assuming that South catches up, therefore we need $\hat{a}_{Mt} = \widehat{T}_{St} = g_F$, which is also Equation (38). Again, we substitute Equations (30) and (37), but now we cannot substitute $m^* = \bar{m}$, as we did to obtain

Equation (39) because this follows from $\chi^* = 0$, which no longer applies. Instead, we leave m as a variable and obtain

$$g_F = \tau_0 + \tau_K \varepsilon_0 (1 - \varepsilon_1 G_t) g_F + \tau_G G_t \bar{E}(1 + \lambda m_t) \tag{68}$$

Then we use Equation (34) again, where we can substitute the righthand side of (68), Equation (37) for $\widehat{K}_t$, and $\bar{E}$ for E_{Mt}, which leads to

$$\varepsilon_0 (1 - \varepsilon_1 G_t) g_F = \tau_0 + \tau_K \varepsilon_0 (1 - \varepsilon_1 G_t) g_F + \tau_G G_t \bar{E}(1 + \lambda m_t) \tag{69}$$

Equations (68) and (69) form the core subsystem, i.e., they are alternatives for the pairs (39 and (40), or (55) and (56). This time, the subsystem contains the variables G and m. It yields the same steady-state value G^* as was the case without government intervention (and catching up), so Equation (41) (which further implies $\varepsilon_X^* = 1$) still applies. The steady-state value for the import propensity is

$$m^* = \frac{1}{\lambda}\left(\frac{\varepsilon_0 \varepsilon_1}{\varepsilon_0 - 1} \frac{(g_F(1-\tau_K) - \tau_0)}{\tau_G \bar{E}} - 1\right) \tag{70}$$

With respect to other steady-state values, Equation (37) holds as before and thus leads again to $\widehat{K}^* = g_F$ (Equation 43). $B^* = \bar{B}$ and $D^* = 0$ hold as before, $h^* = \frac{v}{\mu}(g_F + \delta)$ can be derived from Equations (10) and (43) as before, and $\zeta_t = t_t \frac{\mu}{v}$ can be derived from Equation (17) as before.

Equation (25) now leads to

$$\frac{\mu}{v}(1 - c(1 - t_t) - h_t + m_t) = \chi_t + \zeta_t \tag{71}$$

Setting Equation (24) (for ΔB_t) to zero and substituting the various steady-state values that we already derived yields

$$\frac{\zeta_t m^* - \chi_t (1 - c(1 - t_t) - h^*)}{1 - c(1 - t_t) - h^* + m^*} = \bar{B} g_F \tag{72}$$

Then, we can use (71) to write an expression for ζ_t and substitute this into (72). This makes the $(1 - c(1 - t_t) - h^* + m^*)$ terms cancel out and then reduce to the steady state value for the export variable χ:

$$\chi^* = \frac{\mu}{v} m^* - \bar{B} g_F \tag{73}$$

This steady state χ^*, as well as $t_t = \zeta_t \frac{v}{\mu}$ and the steady state $h^* = \frac{v}{\mu}(g_F + \delta)$ can be substituted into (71), which, after re-arranging, leads to

$$\zeta^* = \frac{\mu}{v} - \frac{g_F(1-\bar{B})+\delta}{1-c} \tag{74}$$

This is exactly the same expression as was found in the case of $\chi^* = 0$, $G^* < 1$ and $\bar{E} > 0$. Consequently, the steady state tax rate will be identical to that case:

$$t^* = 1 - \left(\frac{v}{\mu}\right) \frac{g_F(1-\bar{B})+\delta}{1-c} \tag{75}$$

Because $\chi^* < 0$ is not feasible; Equation (73) implies $\frac{\mu}{v} m^* \geq \bar{B} g_F$. By substituting the steady state value m^*, this condition can be stated in terms of the policy parameter $\bar{E}$:

$$\bar{E} \leq \frac{g_F(1-\tau_K)-\tau_0}{\tau_G\left(\frac{v}{\mu}\lambda\bar{B}g_F+1\right)} \frac{\varepsilon_0\varepsilon_1}{\varepsilon_0-1} \tag{76}$$

This expression is identical to the restriction in Equation (60), which means that there is an upper threshold for the policy parameter $\bar{E}$ that applies to the steady states with $\chi^* = 0$ and $\chi^* > 0$ alike.

Because $m^* \leq \bar{m}$ as dictated by Equation (28), any values of m^* in Equation (70) are also not feasible. This leads to a last requirement for $\bar{E}$ to make a steady state with policy and $\chi^* > 0$ possible:

$$\bar{E} \geq \frac{\varepsilon_0\varepsilon_1}{\varepsilon_0-1} \frac{(g_F(1-\tau_K)-\tau_0)}{\tau_G(1+\lambda\bar{m})} \tag{77}$$

Any value of $\bar{E}$ that is lower than the righthand side of this equation is not feasible because it would require $m^* > \bar{m}$.

Finally, it can be noted that for plausible parameter values, the righthand side of Equation (77) is larger than the righthand side of Equation (59). If this holds, a steady state with $\chi^* > 0$, $G^* = 1$ and $\bar{E} > 0$ does not exist.

Box A4 collects the steady-state values.

Box A4. Steady-state values with policy, $\chi^* > 0$, $G^* < 1$

$$u^* = \mu$$

$$h^* = \frac{\upsilon}{\mu}(g_F + \delta)$$

$$\widehat{K}^* = \hat{a}_M^* = g_F$$

$$E_M^* = \bar{E}$$

$$\zeta^* = \frac{\mu}{\upsilon} - \frac{g_F(1-\bar{B}) + \delta}{1-c}$$

$$t^* = 1 - \left(\frac{\upsilon}{\mu}\right)\frac{g_F(1-\bar{B}) + \delta}{1-c}$$

$$D^* = 0$$

$$B^* = \bar{B}$$

$$\chi^* = \frac{\mu}{\upsilon} m^* - \bar{B} g_F$$

$$m^* = \frac{1}{\lambda}\left(\frac{\varepsilon_0\varepsilon_1}{\varepsilon_0 - 1}\frac{(g_F(1-\tau_K) - \tau_0)}{\tau_G \bar{E}} - 1\right)$$

$$G^* = \frac{(\varepsilon_0 - 1)}{\varepsilon_0\varepsilon_1}$$

Appendix II. Simulations

In order to assess the stability of the steady-state solutions that were derived in Appendix I, including the steady states where exports and government demand co-exist as sources of autonomous demand, we implemented a number of simulations. In each simulation, we fixed parameters to a chosen set of values and simulated from 48 initial conditions for G and E_m. The initial value for the capacity utilization rate u was always equal to μ. Together, these initial values fix the initial values of other variables. The 48 initial values for G and E_m consist of all combinations of 8 different values for G and six different values for E_m, all in $\langle 0,1 \rangle$. The initial values for G are 0.99, 0.9, 0.75, 0.6, 0.45, 0.3, 0.2 and 0.1; the initial values for E_m are 0.988, 0.791, 0.593, 0.395, 0.198 and 0.0198.

Throughout all simulations that we document, we used $c = 0.7, \delta = 0.05, \mu = 0.75, \upsilon = 2.7, \gamma = 0.003, g_F = 0.04, \tau_K = 0.35, \tau_G = 0.06, \overline{m} = 0.2, \bar{B} = 0.4, \varepsilon_1 = 0.4, \iota = 0.05, \varphi = 0.0025$, $\eta = 0.075, \lambda = 0.1$ (but variations in these values do not change the results in a qualitative way). The parameters that we vary are τ_0, ε_0 and $\bar{E}$. With these three parameters, we can create distinct cases in terms of the four quadrants of Table 1 of the main text, the conditions within each of those quadrants, and cases where the steady state with $\bar{E} > 0$ and $\chi^* > 0$ is feasible. Although we cannot explore the entire parameter space of the model, the ten simulation setups that are created in this way provide a representative set of model behaviours.

The outcomes of the simulations are represented by coloured markers in Figure A2.1. Each sub-diagram represents one parameter set or experiment, and the markers correspond to the outcomes of the 48 initial values. The shape and colour of the marker represents the kind of outcome that was observed. For each of the initial values, we run the simulation over 10,000 time steps. We then look at whether there was convergence to the steady state that we predict on the basis of the derivations in Appendix I and as displayed in Table 1 of the main text.

When the simulation outcome corresponds to one of the steady states in Table 1 of the main text, we characterize the outcome as falling behind ($G^* = 1$) or as catching up ($0 \leq G^* < 1$). Convergence to $G^* = 0$ only happens in a few special cases that we will comment on explicitly below. Each individual simulation may also lead to non-convergence, which usually means that the simulation ends with numerical errors because the values of the variables move too far away from a steady state (especially throughout the early periods of the transient stage), or to convergence to non-feasible values, such as $E_M^* > 1$. Outcomes of this kind (catching up, falling behind, non-convergence or non-feasible outcomes) are indicated by circles in the diagram.

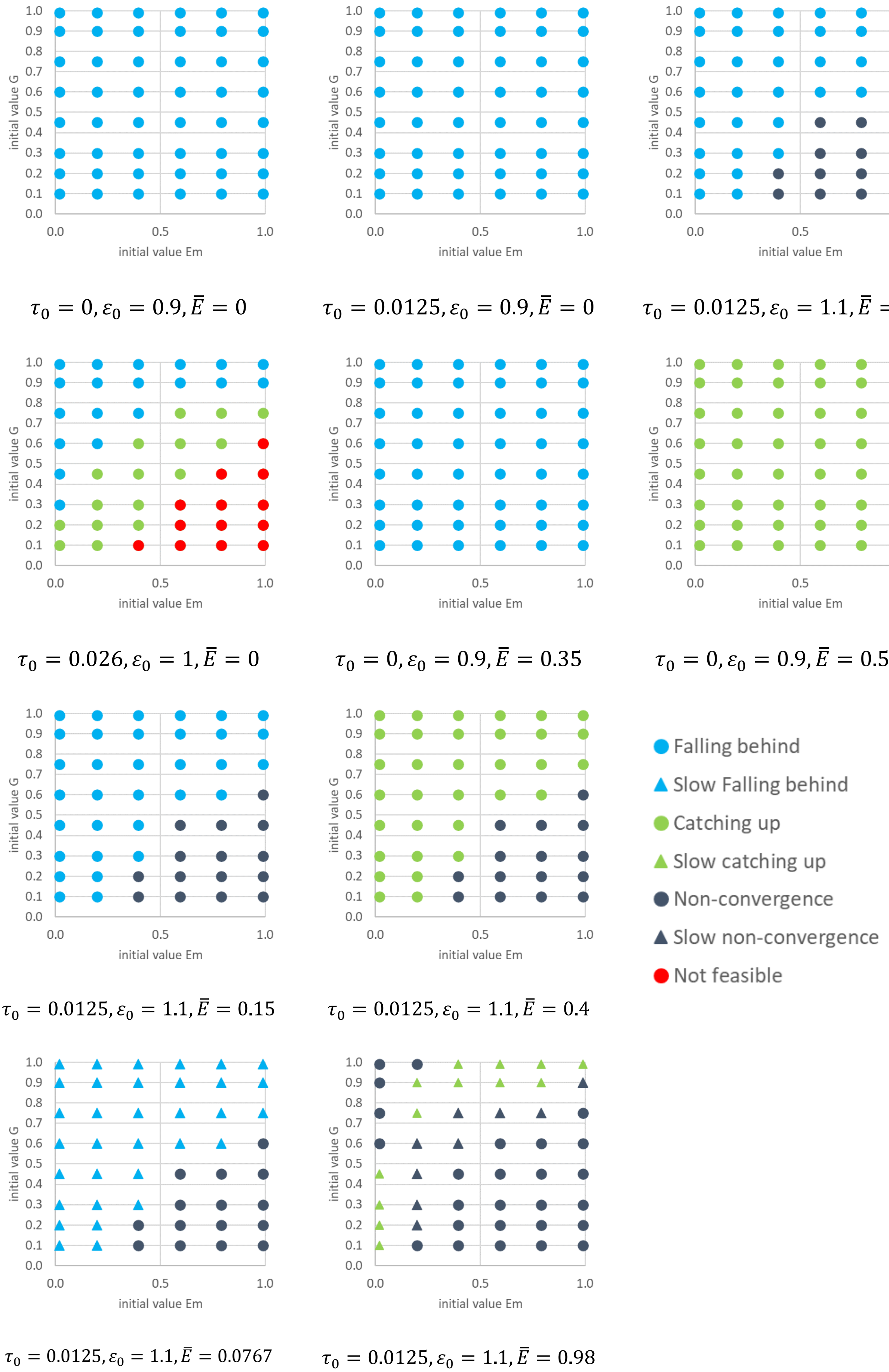


Figure A2.1. Simulation outcomes

A final fifth outcome is where some of the variables, in particular G and E_M, seem to converge to a steady state, but other variables clearly do not, although the latter variables have not moved very far from a steady state. We call this "slow" non-equilibrium dynamics. These simulation outcomes are indicated by triangles. We will comment on the precise nature of these dynamics when they occur.

We discuss this table row-by-row and from left to right. The first simulation ($\tau_0 = 0, \varepsilon_0 = 0.9, \bar{E} = 0$) is what we consider a rather stringent case because domestic exogenous learning is low ($\tau_0 = 0$), and the foreign income elasticity of exports is below 1 for all values of the gap ($\varepsilon_0 < 1$). Because of this, a steady state without policy and $G^* < 1$ is not possible: the conditions for the bottom-left quadrant of Table 1 in the main text are not met. The result is convergence to $G^* = 1$ (falling behind) and $E_M^* \approx 0.23$ for all initial values. The next simulation raises τ_0 to a positive value, but because $\varepsilon_0 < 1$, the conditions for potentially catching up without policy are still not met. The falling behind result has not changed, and $E_M^* \approx 0.025$.

The third experiment also raises ε_0 above 1. As a result, the steady state in the bottom-left quadrant of Table 1 of the main text now exists (the conditions in that cell are met). This economy combines fairly high domestic learning capability with catch-up potential, but the catching-up-without-policy steady state is not stable. Depending on the initial values, the simulation either converges to the steady state with $G^* = 1$, or no steady state is reached. As the figure indicates, non-convergence is observed for combinations of high E_M and low G as initial values. For low E_M and high G as initial values, South falls behind ($E_M^* \approx 0.08$).

We were able to derive the Jacobian matrix of the sub-system of E_M and G that yields the possibility of a steady state $G^* < 1$, as in this experiment. Although we are unable to derive any generic conclusions from this Jacobian, numerical evaluation at the steady state for the parameter values of this simulation experiment (and any other, non-documented experiments in the bottom-left quadrant of Table 1 in the main text) suggest that this steady state is unstable. This is consistent with what we observed in the simulations.

The final experiment without policy ($\tau_0 = 0.026, \varepsilon_0 = 1, \bar{E} = 0$) is a special case: the value $\varepsilon_0 = 1$ makes the steady-state expression for E^* indeterminate, and the value for τ_0 is exactly equal to $g_F(1 - \tau_K)$, thus the conditions for the bottom-left quadrant of Table 1 of the main text are borderline satisfied. Here, we observe a variety of possible outcomes depending on initial values. In the upper-left triangle of the initial values chart, there is falling behind, which is always combined with $E_M^* = 0$. In the lower-right corner of the chart, $E_M^* > 1$, which is unfeasible. In the middle band, which is classified as catching up, $G^* = 0$, and $0 < E_M^* < 1$. There is indeterminacy in this catching-up zone because E_M^* is not a fixed value between the initial values. This is a knife-edge case: any deviation of τ_0 from $g_F(1 - \tau_K)$ makes the outcome either unfeasible ($G < 0, E < 0$ or $E > 1$) or leads to falling behind ($G^* = 1$), and violates the conditions of the bottom-left quadrant of Table 1 in the main text.

The remaining experiments all implement policy ($\bar{E} > 0$). We start with two experiments that are similar to the first non-policy experiment ($\tau_0 = 0, \varepsilon_0 = 0.9$), which resulted in falling behind. First, we set $\bar{E} = 0.35$, which is above the lower threshold and below the upper threshold in the top-right quadrant of Table 1 of the main text. With this value of $\bar{E}$ we expect falling behind. This is indeed what is observed for all initial values. In the next experiment, we raise $\bar{E}$ to 0.55, which puts the policy in the top-left quadrant of Table 1 of the main text (the upper limit to policy in that quadrant is, in this case, 1). As expected, this policy leads to catching up. Hence, these two experiments illustrate the working of the demand-based industrialization policy for the typical case of the very first simulation experiment that we presented.

Next is a policy experiment with $\tau_0 = 0.0125, \varepsilon_0 = 1.1, \bar{E} = 0.15$, which is the third non-policy experiment with a low-ambition policy added. Like in the non-policy case, the initial values in the bottom-right triangle of the chart lead to non-feasible values. Because the 0.15 policy is below the threshold for the upper-left quadrant of Table 1 of the main text but above the non-policy level of E_M^*, we have a higher growth rate but still falling behind for the other cases. The next experiment raises the policy to $\bar{E} = 0.4$, which is above the lower threshold of the top-left quadrant of Table 1 of the main text and also still below the upper threshold there. This leads to the falling behind cases of the previous experiment, turning to catching up.

In the final two experiments, we explore the two narrow "special" ranges of $\bar{E}$ where we do not expect $\chi^* = 0$ with policy. The first of these cases is the lower special range, where we expect falling behind ($G^* = 1$). The results look very similar to the case $\tau_0 = 0.0125, \varepsilon_0 = 1.1, \bar{E} = 0.3$: there is a region of the chart where we observe falling behind in the sense that the gap convergence to $G^* = 1$. But, also, as expected, the values for m and χ do not converge: they keep on rising or falling depending on the initial value. Hence, this is a case of the slow non-equilibrium dynamics with falling behind.

The final simulation experiment is a case in the upper special range for $\bar{E}$, hence here we expect catching-up ($G^* = 1$). There are areas at the upper-left and bottom-right corners of the chart where non-convergence is observed. In the middle band, there is always slow non-equilibrium dynamics, as in the previous case. In these cases, the final values of χ are always positive. In some of these cases, the final values of ε_X that is observed is larger than one, and this is labelled as slow non-convergence because $\varepsilon_X > 1$ implies movement away from any steady state. Note, however, that at the end of these slow dynamics, the technology gap is still below 1. In other cases, we observe final values $\varepsilon_X < 1$ and $G < 1$. These cases are labelled as slow catching up.