Export-led Growth, Global Integration, and External Balance of Small Island Developing States

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Abstract

Small, open developing economies in general, and small island developing states (SIDS) in particular, have specific macroeconomic characteristics due both to their openness and their small size. Small size means they can never have fully independent capital-intensive domestic economies, so to raise incomes they must become thoroughly integrated into the global economy. The export sector thus becomes the engine of growth; it provides domestic income, which is spent on domestic goods and imports, driving overall economic output through a multiplier effect. Building on work within the Caribbean structuralist tradition, this paper presents a demand-driven model that includes capital accumulation and external debt. Given the limited data available for many small island states, the model explicitly represents the external macroeconomic balance. An aggregate representation of the national economy is derived formally from a two-sector model, following models of a petroleum exporting country developed Seers and Bruce and Girvan. The model's performance was evaluated against the historical performance of the Caribbean countries of Barbados, Jamaica, and Trinidad and Tobago.

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Introduction

The economies of small, open, developing states have particular macroeconomic characteristics due to their openness, their economic structure, and their small size. Within this group, many small island developing states (SIDS) are also readily accessible to shipping. The English-speaking Caribbean islands have produced a number of prominent economists who focused attention on those special characteristics, and who had a significant influence over national and regional policy. Lewis (1954, 1979) introduced the idea of a "dual" economy in his analysis of the transformation from largely agrarian economies with abundant labor to industrialized economies. Arguing that domestic capital is scarce, Lewis suggested that countries should seek foreign investors, a strategy since dubbed, somewhat critically, as "industrialization by invitation". In light of subsequent experience, Demas (2009, first published 1965) argued that this pathway can only ever lead to a partial transformation. Small economies cannot become "balanced", with light and heavy manufactures; raw materials production and high technology; and robust agricultural, industrial and service sectors. Rather, they must specialize. Moreover, because beyond a certain point small economies cannot reap the gains of increasing scale on the basis of their own consumption, their specialization must be oriented towards exports. Export-oriented sectors then become leading sectors, in that GDP growth tracks export growth to a much greater degree in small economies than it does in large ones.

The theory and policy advocated by Lewis and Demas came under fierce attack as the English-speaking Caribbean islands gained their independence in the 1960s and 1970s. In part, the attack was associated with a self-defined New World Group of young economists (N. Girvan 2006). One influential model emerging from this group was the Plantation Economy model of Best (1968), of which a central theme was that the export sector in Caribbean countries developed initially to serve a Metropolitan economy, and so was not fully integrated into the domestic economy. In a related analysis, Girvan and Girvan (1970) argued that the development and exploitation of mineral resources in small economies by larger ones led to an export sector minimally connected to the rest of the domestic economy. These critiques, although they may have been unduly critical of prior theorists (Figueroa 1996), highlighted the substantial challenges that small economies face in effectively using the export sector to drive a transformation of the domestic economy.

Kraay and Easterly (1999) questioned whether it is appropriate to focus attention on small island economies. They demonstrated that such states tend to have higher GDP per capita compared to their neighbors, and urged instead a focus on landlocked countries. However, while landlocked countries face very serious challenges that should be seriously addressed, SIDS will always be driven by forces out of their direct control. In particular, they rely heavily on export demand and are vulnerable to storms and sea level rise, which are intensifying with climate change (Nurse et al. 2014). As the countries are too small – in terms of land area and population – to support a self-reliant industrial economy, economic development depends on their integration into a continually changing global economy. Without that integration, increases in GDP per capita are misleading, reflecting what Demas (2009 [1965]) called growth without development. In short, while small island developing states may have comparatively high GDP per capita, it does not secure them a restful existence.

Drawing on the foregoing, we can characterize the economic structure of small island developing states as being composed of one or more export-oriented sectors, which may be capital or labor-intensive, and a domestically-oriented labor-intensive sector. Investment goods are imported. An essential question is how the export-oriented sector is inserted into both the global economy and the rest of the domestic economy. A recurring theme in Caribbean economic thought, particularly in Demas (2009 [1965]), Best (1968), and Girvan and Girvan (1970) is that the foreign exchange earned by the export-oriented sectors must be used to fund the transformation of the rest of the domestic economy, suggesting that while an effective insertion into the global economy is necessary for development, it must be accompanied by an equally effective domestic insertion. The models developed in this theoretical tradition are structuralist (Chenery 1975; Taylor 1989; Lin 2012; Ocampo, Rada, and Taylor 2013), in that persistent structural features of the economy strongly influence its trajectory. They are also demand-led (Setterfield 2002), in that export demand drives growth, which stimulates capital accumulation. As emphasized in balance of payments-constrained models (Thirlwall 1979; Hussain 2006, 27), exports are particularly important for developing and small open economies because they are the only component of demand that can generate foreign exchange to purchase goods and services that the domestic economy cannot supply. In contrast, conventional macroeconomic models are typically supply-led, in that capital accumulation drives output growth.

In this paper we present a demand-led, structuralist model to be applied to small island developing economies. The model was developed in the context of a set of Caribbean climate adaptation scenarios (Drakes et al. 2016) as an exercise in applied economics. Data limitations effectively restrict the model to the "external" macroeconomic balance, or the trade gap (Taylor 1989), and only permit an aggregate representation of the national economy. We derive the aggregate model formally from a two-sector model, in line with Caribbean structuralist economic theory. This was a strategy adopted by Seers (1964) to derive a simple model for a petroleum exporter, and by Bruce and Girvan (1972), who recast Seers' model in Keynesian terms.

The present model contributes to the literature by considerably extending the approach of Seers and of Bruce and Girvan. It is a disequilibrium, but equilibrium-seeking, dynamic model. As it represents only the external balance, the model can be used to understand how an exogenous export demand drives the national economy and the external debt, but not to study public spending, central bank operations, and similar internal dynamics. The focus on the external balance is reminiscent of balance of payments-constrained growth models (Thirlwall 1979, 2011), but unlike those models it is meant to apply in the short and medium term, and not only the long run, so we do not impose a zero trade balance. Gross domestic product (GDP)[1] is driven mainly by exports, although it also responds to changes in population. An import propensity determines the level of imports, while the investment rate depends negatively on debt and positively on utilization of capital. The external balance is then computed, in which net addition to external liabilities is given by the gap between imports and exports, thereby increasing or decreasing the external debt.

In the next section we present the two-sector production model. We then aggregate to one sector and add investment and debt dynamics. After calibrating the model we discuss the results and conclude.

The two-sector model

As discussed in the introduction, we construct a national model by starting from a two-sector model and then aggregating. The *export* sector produces goods for export, but some products from the sector might also be consumed domestically, whether in final consumption or as an intermediate input to the domestic goods sector. The *domestic* sector produces goods for domestic consumption that might also be used as intermediate inputs into the export sector; for example, domestic services, construction, small manufactures or food production. Each sector therefore has some demand for the other's outputs. We express nominal wages and domestic prices in the local currency, and debt and external prices in the world currency, taken to be US dollars (USD). As in Seers (1964) and Bruce and Girvan (1972), export demand drives domestic demand through a multiplier. In Seers and Bruce and Girvan, this operates through domestic wage income, which may derive from government employment. We allow for intermediate consumption between

[1] Arguably, gross national income (GNI) is more relevant than GDP in a model focusing on externally-oriented production in which a significant portion of the capital in the export sector is foreign-owned. However, the available data are insufficient to test and calibrate such a model.

sectors in the domestic economy, but as we focus on the external balance we exclude government expenditure and taxation.

The main drivers and feedbacks are shown in Figure 1. Export demand contributes to GDP and tends to reduce debt levels. GDP both fuels consumption and supplies it, while some consumption adds to imports. Investment also adds to imports, and the gap between imports and exports contributes to debt; remittances, not shown in the figure, also affect debt accumulation. GDP growth, the debt-to-GDP ratio, and capacity utilization all influence investment, where utilization is determined by the ratio of GDP to the capital stock.

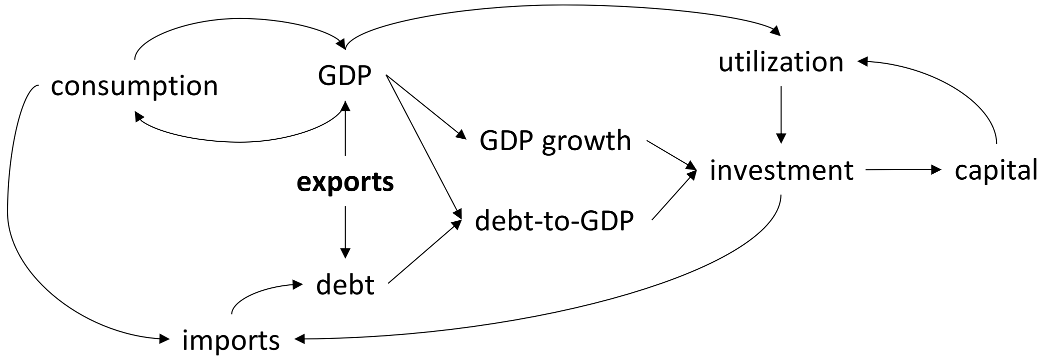

Figure 1: Main drivers and feedbacks in the export-led model

All prices in the model are exogenous, including the exchange rate. For the domestic sector this requires some explanation. The price level of consumption, and thus the real wage in the domestic goods sector, is influenced by the cost of imported intermediate and final consumption goods and the wage rates prevailing in the export sector. Holder and Worrell (1985) found, for Barbados, Jamaica, and Trinidad and Tobago, that by far the strongest influence on the price of non-tradables (corresponding to the domestic sector in this model) is the price of tradables (corresponding to the export sector and imported goods in this model). Labor costs had a small and sometimes statistically insignificant effect, while bank lending rates had a statistically significant but not very large effect. In contrast, the lagged price level did explain wage rates. As the prices of tradables are determined in world markets, we assume exogenous prices and implicitly compute wage rates from prices by assuming constant wage shares of income in each production sector.

Denoting the export sector by a subscript x and the domestic sector by a subscript d, the input-output relationships for the economy relate production Y_x, Y_d to demand for exports X, domestic consumption of export and domestic goods C_x, C_d, and demand for intermediate goods, net of own-use,

$$Y_x = X + C_x + a_{xd} Y_d, \tag{1}$$

$$Y_d = C_d + a_{dx} Y_x. \tag{2}$$

This is a conventional input-output framework, but net of intermediate exchanges within each sector. We expect such exchanges to be present – for example, we expect a demand for domestic goods by the domestic sector – but are compelled by data restrictions to limit the number of free parameters.

On the consumption side, total income – GDP plus remittance inflows R plus net new external liabilities $e\ell$ (where e is the exchange rate) – equals total expenditure – consumption of domestically produced goods, $P_x C_x$ and $P_d C_d$, plus consumption of imported goods $P_m C_m$ and intermediate imports $P_m m_x Y_x + P_m m_d Y_d$, plus imported capital goods (investment $P_i I$), and remitted profits Π_r,

$$PY + R + e\ell = P_x C_x + P_d C_d + P_m \left(C_m + m_x Y_x + m_d Y_d \right) + P_i I + \Pi_r . \tag{3}$$

All prices in this expression are in the domestic currency. We write the corresponding world prices with asterisks,

$$P_x = eP_x^*, \quad P_m = eP_m^*, \quad P_i = eP_i^*. \tag{4}$$

Net new external liabilities are computed as a residual in the model. Remittance income arrives from a variety of sources, including investment income and remitted wages from family members working abroad. For simplicity, we assume that personal remittance income is proportional to GDP, with a factor ρ_{pers},

$$R = \rho_{\text{pers}} PY. \tag{5}$$

Remitted profits (an outflow) represent investment income to overseas investors, which we write as a rate ρ_K applied to the capital stock valued at the current price of investment goods, P_i,

$$\Pi_r = \rho_K P_i K. \tag{6}$$

All consumption in the model is paid for out of wages or mixed income. Consumption patterns adjust gradually to changes in wages, so rather than the current year's wage receipts W, consumption is related to (exponentially) smoothed wage income $\bar{W}$. We set a floor to consumption at a basic consumption demand c_0 per person, for a population N, and apply a marginal saving rate s_w to marginal income above the level needed for basic consumption. Basic consumption is supplied fully by the domestic goods sector, while non-basic consumption is split between consumption of imported goods, with a share m, of which domestically-produced domestic goods supply a share c_d, and domestically-produced export goods supply a share c_x. The consumption shares sum to one,

$$c_x + c_d = 1. \tag{7}$$

With these assumptions, the different components of consumption are given by

$$P_d C_d = P_d c_0 N + c_d \left(1 - m\right)\left(1 - s_w\right)\left(\bar{W} - P_d c_0 N\right), \tag{8}$$

$$P_x C_x = c_x \left(1 - m\right)\left(1 - s_w\right)\left(\bar{W} - P_d c_0 N\right), \tag{9}$$

$$P_m C_m = m\left(1 - s_w\right)\left(\bar{W} - P_d c_0 N\right). \tag{10}$$

Combined, they give total consumption expenditure,

$$P_d C_d + P_x C_x + P_m C_m = P_d c_0 N + \left(1 - s_w\right)\left(\bar{W} - P_d c_0 N\right). \tag{11}$$

The smoothed wage at the current time step is related to the current wage and the smoothed wage in the previous time step through the relation

$$\bar{W} = zW + \left(1 - z\right)\bar{W}_{-1}, \tag{12}$$

where z is a rate in terms of the time step, which is taken to be a quarter. The wage bill, in turn, is equal to output multiplied by the wage, which we express as wage shares ω_x and ω_d multiplied by prices in the export and domestic goods sectors,

$$W = P_x \omega_x Y_x + P_d \omega_d Y_d . \tag{13}$$

On the production side, GDP is equal to the production of goods for export and goods for domestic consumption produced by either the export or domestic-goods sectors,

$$PY = eP_x^* X + P_x C_x + P_d C_d . \tag{14}$$

Substituting the expressions for consumption, equations (9) and (8), into this expression,

$$PY = \underbrace{eP_x^* X}_{\substack{\text{exports}\\ \text{direct}}} + \underbrace{P_d c_0 N}_{\substack{\text{basic cons.}\\ \text{direct}}} + \underbrace{(1-m)(1-s_w)\left(\bar{W} - P_d c_0 N\right)}_{\text{indirect}}. \tag{15}$$

Total imports, *M*, in domestic currency are given by the sum of imported consumption goods and investment expenditure,

$$M = P_m C_m + P_i I = m(1-s_w)\left(\bar{W} - P_d c_0 N\right) + P_i I. \tag{16}$$

Following Thirlwall (2011, 322), we allow imports to depend on the domestic price relative to the price of imports, with an elasticity, ε_m,

$$m = m_0 \left(\frac{eP_m^*}{P_d} \right)^{\varepsilon_m}. \tag{17}$$

The expressions above can be combined to construct an aggregate model.

The aggregated one-sector model

To construct an aggregate model, we first substitute the expressions for the smoothed and instantaneous wage, equations (12) and (13), into the expressions for consumption, equations (9) and (8). This gives two linear equations in four variables: Y_x, Y_d, C_x and C_d. The input-output relations in equations (1) and (2) give two further linear equations in those variables. The result is four linear equations for four unknowns. In matrix form, they are

$$\begin{pmatrix} 1-\theta z c_x \Phi \omega_x & -a_{xd} - z c_x \Phi \omega_d \\ -a_{dx} - \theta z c_d \Phi \omega_x & 1 - z c_d \Phi \omega_d \end{pmatrix} \begin{pmatrix} Y_x \\ Y_d \end{pmatrix} = \begin{pmatrix} X \\ c_0 N \end{pmatrix} + \begin{pmatrix} c_x \\ c_d \end{pmatrix} \Phi \left[(1-z) \frac{\bar{W}_{-1}}{P_d} - c_0 N \right], \tag{18}$$

where Φ is a factor translating total final demand to demand for domestic goods,

$$\Phi \equiv (1-m)(1-s_w). \tag{19}$$

and θ is the ratio of the domestic price for export goods to the price for domestic goods,

$$\theta = \frac{P_x}{P_d} = \frac{eP_x^*}{P_d}. \tag{20}$$

The right-hand side of equation (18) contains exports *X*, the previous-period smoothed wage$\bar{W}_{-1}$, and the population *N*. The coefficients on the left-hand side depend on prices as well as model parameters to be estimated from data.

For notational simplicity, the unwieldy expressions in equation (18) can be replaced by

$$\begin{pmatrix} 1-A_{xx} & -A_{xd} \\ -A_{dx} & 1-A_{dd} \end{pmatrix} \begin{pmatrix} Y_x \\ Y_d \end{pmatrix} = \begin{pmatrix} X \\ c_0 N \end{pmatrix} + \begin{pmatrix} c_x \\ c_d \end{pmatrix} \Omega. \tag{21}$$

Solving this system gives expressions for real output in the export and domestic goods sectors,

$$Y_x = \frac{(1-A_{dd})(X + c_x \Omega) + A_{xd}(c_0 N + c_d \Omega)}{\Delta}, \tag{22}$$

$$Y_d = \frac{A_{dx}(X + c_x \Omega) + (1-A_{xx})(c_0 N + c_d \Omega)}{\Delta}. \tag{23}$$

where Δ is the determinant of the matrix in equation (21),

$$\Delta = (1-A_{xx})(1-A_{dd}) - A_{xd} A_{dx}. \tag{24}$$

Inserting these expressions into equation (13), which expresses the wage bill in terms of prices, wage shares, and output, the wage bill can be written as a sum of three terms,

$$W = W_X + W_N + W_\Omega, \tag{25}$$

where

$$W_X = \frac{\omega_x e P_x^* \left(1 - A_{dd}\right) + \omega_d P_d A_{dx}}{\Delta} X, \tag{26}$$

$$W_N = \frac{\omega_x e P_x^* A_{xd} + \omega_d P_d \left(1 - A_{xx}\right)}{\Delta} c_0 N, \tag{27}$$

$$W_\Omega = \frac{\omega_x e P_x^* \left[\left(1 - A_{dd}\right) c_x + A_{xd} c_d\right] + \omega_d P_d \left[A_{dx} c_x + \left(1 - A_{xx}\right) c_d\right]}{\Delta} \Omega. \tag{28}$$

When combined with the smoothed wage formula in equation (12), the aggregate production model is closed. The logic is shown in Figure 2: exogenous prices, population, and export demand drive the model. Combined with the lagged smoothed wage bill, these variables determine output in each sector, which subsequently determine the instantaneous wage bill. The instantaneous wage then contributes to the next-period lagged smoothed wage bill.

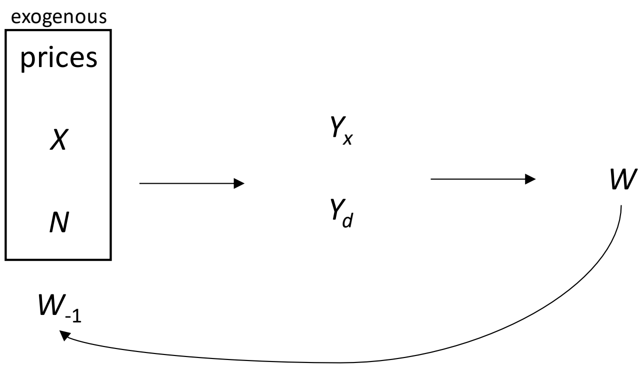

Figure 2: Flow of calculation in the aggregate production model

Balance of payments, debt and investment

Small size and dependence on export income makes small island developing states prone to external imbalances and fluctuating levels of debt. While in the long run fiscal and financial forces reduce imbalances, ensuring that Thirwall's Law holds (Thirlwall 1979; Hussain 2006), in the short and medium run significant imbalances are the norm, affecting both daily life and domestic politics. In the model, external debt, *D*, is denominated in the international currency (USD). Debt is increased by interest accruals at a rate *i* and net new external liabilities, ℓ,

$$\Delta D = iD_{-1} + \ell. \tag{29}$$

Net new external liabilities are created whenever imports and net remittance inflows exceed exports, which can be found by subtracting GDP in production terms, equation (14), from GDP in consumption terms, equation (3). The result is

$$e\ell = M - eP_x^* X + \Pi_r - R. \tag{30}$$

Remitted profits depend on the capital stock from equation (6), while imports include investment goods as in equation (16). Thus, the external balance is tied to capital accumulation. Capital stocks follow perpetual inventory dynamics, with the growth rate of the capital stock given by

$$\hat{K} = g - \delta. \tag{31}$$

Here, $g = I/K$ is the investment rate and δ is the depreciation rate. Investment decisions are driven by expectations of further real growth, short-term changes in capacity utilization, and debt. Denoting capacity utilization by u, the debt-to-GDP ratio by v and a reference level of v by v^*, the investment rate is given by

$$g = g_0 + \overline{\hat{Y}} + g_u(u-1) - g_d(v - v^*). \tag{32}$$

In this expression, the bar over the growth rate of real GDP indicates an exponentially smoothed average; we discuss the calculation of real GDP from nominal GDP below. The parameters g_0, g_u, and g_d are all positive. Assuming a constant capital productivity, the change in utilization is given by the ratio of the GDP growth rate and the growth rate of the capital stock,

$$\hat{u} = \hat{Y} - \hat{K}. \tag{33}$$

To compute real GDP (and the GDP price level), we construct a Laspeyre's index. Denoting the share of GDP output going to exports by ξ,

$$\xi \equiv \frac{eP_x^* X}{PY}, \tag{34}$$

the GDP deflator is equal to a weighted sum of the inflation rate of prices for domestic goods and prices of exports. Using a hat to indicate a growth rate, we have

$$\hat{P} = (1-\xi)\hat{P}_d + \xi\hat{P}_x. \tag{35}$$

With this definition, the growth rate of real GDP is computed as

$$\hat{Y} = PY - \hat{P}, \tag{36}$$

with PY given by equation (15).

Calibration

The model has been implemented in the Vensim system dynamics (SD) software[2], and we followed recommended procedures for constructing, calibrating and evaluating SD models. In general, SD modelers do not trust any single test as establishing the validity of a model. Rather, a series of tests gradually builds confidence in the model (Forrester and Senge 1980; Martinez-Moyano and Richardson 2013, 112). Some of these are structural: the model structure should be realistic, all parameters should have real-world meanings, and each equation should be logically plausible. We followed these procedures in model construction documented above. Other confidence-building procedures involve parameter estimation: using data below the level of aggregation of the model whenever possible (Graham 1976, 549), separately validating and estimating the model's components (Homer 2012 [1983]), and calibrating against historical data (Oliva 2003).

As with many SD models, data limitations prevent us from using data below the level of aggregation of the model, so we follow the other two procedures. Using historical data we separately calibrate two components: GDP and imports, and investment and debt. Time series data were collected for Barbados, Jamaica and Trinidad and Tobago from underlying national accounts data used to prepare the Penn World Table version 8.1 (PWT81) (Feenstra, Inklaar, and Timmer 2015), including GDP Y (q_gdp)[3], exports X (q_x), imports M (q_m), investment I (q_i), and exchange rates e (xr). Corresponding price levels were computed using nominal values: e.g., the price level of consumption (used as a proxy for P_d) was computed as v_c/q_c, and similarly for the price levels of imports (P_m), exports (P_x), investment (P_i), and GDP (P). Exports and GDP were

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[2] Vensim DSS version 6.4E (http://www.vensim.com).

[3] The variable in the public data set is listed in parentheses.

used to compute exports as a share of GDP (ξ). Depreciation rates δ (depr) were taken from the prepared PWT81 tables. To compute debt levels (D), we used the World Bank World Development Indicators (WDI), subtracting reserves (using FI.RES.TOTL.DT.ZS) from external debt stocks (DT.DOD.DECT.CD). Personal remittances as a share of GDP were taken from WDI series BX.TRF.PWKR.DT.GD.ZS. Population data were taken from the UN (UN DESA 2015).

To compute capital stocks (K), we first constructed a time series from the investment and depreciation data using the perpetual inventory method. This synthetic capital stock time series was not used directly in calibration, but was used indirectly to set a bound on the initial value for the capital stock. The most uncertain parameter in the perpetual inventory method is the starting value for the capital stock. However, that initial value becomes less important over time due to depreciation and growth. In this method the capital stock at time t is computed as

$$K_t = \left(1-\delta_{t-1}\right)K_{t-1} + I_{t-1}. \tag{37}$$

Solving this recurrence relation gives an expression in terms of historical investment and depreciation rates, and the assumed initial value for the capital stock, as

$$K_t = K_0 \prod_{u=0}^{t-1}\left(1-\delta_u\right) + \sum_{u=0}^{t-1}\left[I_u \prod_{v=u+1}^{t-1}\left(1-\delta_v\right)\right]. \tag{38}$$

The initial value appears in the first term, so if it initially has relative error of ε_0, by time t the relative error is smaller,

$$\varepsilon_t = \varepsilon_0 \frac{K_0}{K_t} \prod_{u=0}^{t-1}\left(1-\delta_u\right). \tag{39}$$

Investment and depreciation data series for Barbados start in 1960, for Jamaica in 1953, and for Trinidad and Tobago in 1950. However, we expect the model parameters to vary slowly over time due to structural changes, so we do not calibrate against the full historical data set. Rather, we start the calibration runs in 1986, after several Caribbean countries implemented financial reforms. By that time, a relative error of ±100% is reduced to ±15% in Barbados, ±5% in Jamaica, and ±1% in Trinidad and Tobago. We constructed time series by assuming a capital-output ratio of 2.5 years in the initial year of the capital accounting calculations, but in calibration runs we allowed the 1986 value of the capital stock to vary by the relative errors quoted above.

SUB-MODEL CALIBRATION

Following recommended practice in SD modeling, we separately calibrated different sub-models within the full model: investment, GDP, debt, and imports. We used the Powell (1964) optimizer available in Vensim. For each sub-model, we provided external data series for exports, depreciation rates, prices (including the exchange rate), and population. We then provided additional external data, depending on the sub-model.

We weighted each calibration variable by the inverse mean square root error. With this practice, the errors can be interpreted as confidence intervals, assuming that deviations, as a function of the fitted parameters, are approximately quadratic near the estimated parameter values. Because we do not know the mean square root error *a priori*, we carried out multiple calibration runs manually, using the estimated errors for the weights, until the estimates converged. This procedure required either one or two iterations.

A complication in calibrating (and running) the model is that there is no guarantee that the sector receipts will cover sector costs. As a diagnostic, we calculated profit shares as

$$\pi_x = 1 - \left(\omega_x + \frac{P_d}{P_x} a_{dx} + \frac{P_m}{P_x} m_x \right), \tag{40}$$

$$\pi_d = 1 - \left(\omega_d + \frac{P_x}{P_d} a_{xd} + \frac{P_m}{P_d} m_d \right). \tag{41}$$

We then constrained the ranges of the variables ω_x, ω_d, m_x, m_d, a_{dx} and a_{xd} such that, aside from acute periods when profits were squeezed, these values were positive in Barbados, Trinidad and Tobago, and in the export sector in Jamaica. It did not prove possible to construct positive profits in the domestic sector in Jamaica given all the other calibration constraints. We note, as a possible source of the discrepancy, that all three price series in Jamaica – P_d, P_x, P_m – were, unlike in the other two countries, equal to each other. However, in the same period the price levels of consumption and GDP were not constant (Feenstra, Inklaar, and Timmer 2015), suggesting possible problems in the underlying data. In the calibration runs we allowed negative profits in the domestic sector in Jamaica.

GDP and imports

For GDP, we used the observed data for imports and estimated parameter values for the technical coefficients a_{xd} and a_{dx}, the base consumption level c_0, marginal domestic consumption from exports, c_x, saving out of wages s_w, the wage smoothing parameter z, initial value for the smoothed wage, and the wage shares ω_x and ω_d. We used data from 1986 to 2011 for both GDP and exports as a share of GDP for the calibration, but they are not independent, so we estimated 9 parameters using 26 data points.

Imports are tied to GDP through demand for imported intermediate goods for domestic production. We have two parameters for imported consumption goods, in equation (17): the scale parameter m_0 and the elasticity ε_m. To these we add the import coefficients *mx* and *md* in equation (3). Calibrating against import data from 1986 to 2011 gives 4 parameters calibrated against 26 data points.

Investment and debt

To calibrate the investment function, we provided, in addition to the common set of external data, observed time series for GDP. For Jamaica, which has a full debt time series, we also provided debt, D. For Barbados and Trinidad and Tobago, which do not have full debt time series, we used the calculated debt levels. We then estimated values in the investment function, equation (32): the base investment rate g_0, utilization coefficient g_u, debt coefficient g_d, reference debt-to-GDP level v^*, and the initial value for utilization. We also allowed the initial capital stock to vary by the amounts noted above.

For debt, we fit the interest rate, i, initial external debt, and remitted profits as a rate applied to capital, ρ_K. In both Barbados and Trinidad and Tobago the initial debt level had to be estimated. Furthermore, in Trinidad and Tobago there were substantial changes to the ownership and management structure of the oil and gas sector over 1986-1999 (Boopsingh and McGuire 2014). The structural break appeared to occur near 1997, so we fit two values for the rate of remitted profits, one for before and one for after 1997.

To 26 data points for investment in all countries, we added 12 debt series data points for Barbados and Trinidad. To the 6 investment parameters in all countries we added 4 debt parameters for Barbados (11 parameters against 38 data points) and 5 debt parameters for Trinidad and Tobago (11 parameters against 38 data points).

In Jamaica, we calibrated investment separately from debt. Fitting the investment data from 1986 to 2011 gave 6 parameters calibrated against 26 data points, while for debt we had 3 parameters against 26 data points.

RESULTS

We report goodness-of-fit statistics for GDP, investment, debt and imports in Table 1. Particularly problematic values are indicated by an underline. The first three columns in the table are the R^2 (coefficient of determination), Durbin-Watson, and mean absolute percentage error. The last three columns are the components of a Theil decomposition of the model-data variance (Sterman 1984). The statistic U_m is the fraction of the mean squared error due to difference in the mean, U_v is due to differences in variance, and U_c is due to point-to-point covariance. The three values sum to one by construction. Ideally, the model reproduces both the mean and the variance, so the model faithfully reproduces the data series when $U_c = 1$.

Due to the missing debt data in Barbados and Trinidad and Tobago, we used the debt data series mainly to constrain the fit to the investment data, so results for debt are not shown in the table for those two countries. The model performs well on most metrics. We focus on the problematic ones, which are underlined in the table. The Durbin-Watson statistics is less than one for GDP in Barbados, and for GDP and imports in Jamaica, indicating residual serial correlation. The mean absolute percentage errors are generally less than or approximately equal to 10%, aside from investment in Trinidad and Tobago, where it is 15% (and the R^2 statistic is 0.63). The Theil statistics generally suggest fidelity, although there is a bias in the mean value of GDP for Jamaica, and the model does not fully capture variance in investment in Barbados and Trinidad and Tobago, debt in Jamaica, and imports in Barbados.

Table 1: Goodness-of-fit statistics (underlined values indicate a potential problem)

				Theil		
	R^2	DW	MAPE	U_m	U_v	U_c
Barbados						
GDP	0.85	<u>0.45</u>	3.1	0.06	0.03	0.91
Investment	0.79	1.03	8.9	0.00	0.08	0.92
Imports	0.94	1.77	4.4	0.00	<u>0.27</u>	<u>0.73</u>
Jamaica						
GDP	0.85	<u>0.85</u>	3.9	<u>0.20</u>	0.00	<u>0.80</u>
Investment	0.92	1.07	4.8	0.00	0.04	0.96
Debt	0.93	1.26	10.7	0.00	<u>0.21</u>	<u>0.78</u>
Imports	0.69	<u>0.69</u>	8.2	0.00	<u>0.35</u>	<u>0.64</u>
Trinidad and Tobago						
GDP	0.96	1.45	5.8	0.04	0.02	0.93
Investment	0.63	1.78	<u>15.4</u>	0.00	<u>0.23</u>	<u>0.77</u>
Imports	0.93	2.00	7.4	0.01	0.00	0.99

To gain a better understanding of what the goodness-of-fit statistics represent, an example of a good fit – GDP in Trinidad and Tobago – is shown in Figure 3. An example of a less-good fit – investment in Trinidad and Tobago – is shown in Figure 4. As can be seen, investment generally follows the observed trend, but fails to capture much of the variance, suggesting that factors other than utilization and debt levels significantly influence investment. That is, indeed the case, as it is driven by investment trends in the oil and gas industry. Oil prices had fallen around 2000 and appeared to be steadily rising around 2005. A refinement to the model to include the crude oil price as an explanatory variable.

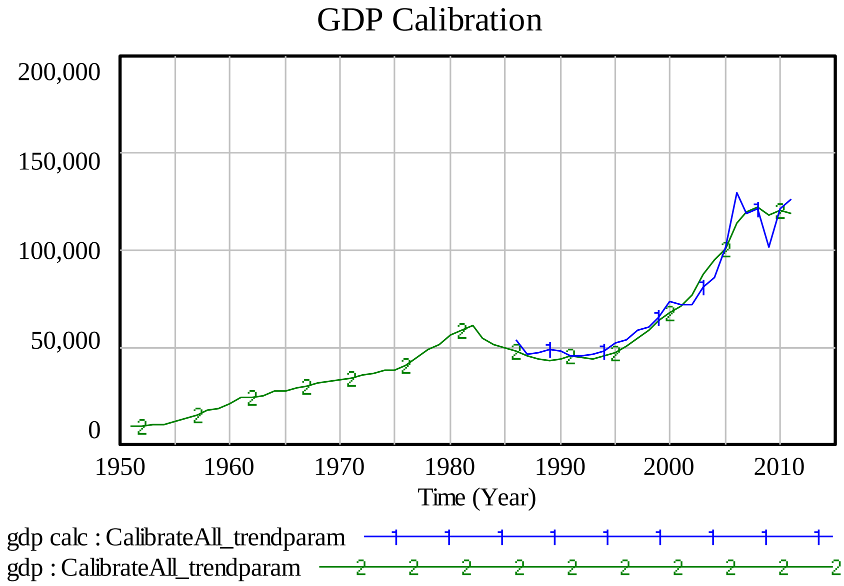

Figure 3: A good fit: GDP in Trinidad and Tobago

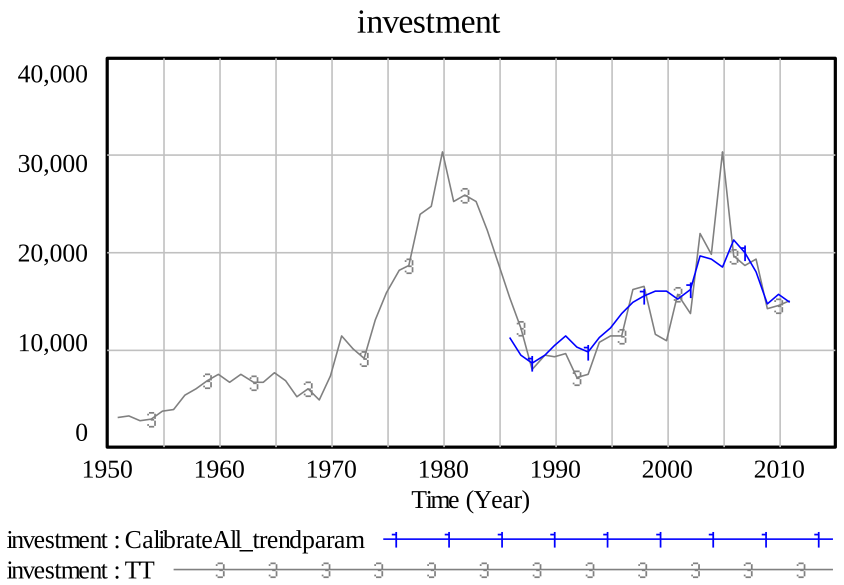

Figure 4: A less-good fit: Investment in Trinidad and Tobago

Estimated values for selected parameters are shown in Table 2. Some of the values are equal to the imposed upper or lower limit of the allowed range. These are underlined in the table. The estimated parameters are not unreasonable on their face. Investment in Trinidad and Tobago is less sensitive to changes in utilization and debt levels than either Barbados or Jamaica; as it is the wealthiest of the three countries and an oil exporter, this is a plausible result. Jamaica, with the lowest per capita income, has a lower estimated threshold level of debt-to-GDP ratio, which is also plausible.

Domestic consumption of export-sector goods was estimated to be zero in all countries; this is not unreasonable at this level of aggregation, although it is likely that at least some goods intended for export are consumed domestically. Imports of consumer goods rise with per capita income, although the estimate of zero for Jamaica is problematic (the upper limit of the confidence interval is 0.8%). Wage shares are higher in the domestic sector, but this is because we set different limits; wage shares are allowed to be higher in the domestic sector because they are assumed to be less capital intensive.

The parameter estimates are consistent with considerable intermediate exchange within the national economies between the export and domestic sectors. This is a positive outcome, if true, because it is indicative of domestic insertion of the export sector. Imports of intermediate goods are lower in the domestic sector than the export sector in all countries, which is reasonable, as the export sectors are more thoroughly integrated into the global economy.

Remitted profits are expected to be higher, the more capital is owned by foreign entities. We thus expect it to be highest in Trinidad and Tobago, and particularly high before the change in the ownership structure. This expectation is met with the estimated parameters. However, the estimate of zero for Barbados is suspect, as the country has seen substantial foreign direct investment, and some profits are remitted.

Table 2: Estimated parameter values (underlined values are at the upper or lower end of the allowed range)

Parameter	Barbados	Jamaica	Trinidad & Tobago
g_0	0.017	0.046	0.040
g_u	0.101	0.282	0.048
g_d	0.017	0.013	0.001
v^*	1.889	0.644	2.000
m_0	0.177	0.000	0.420
ε_m	-0.123	-2.802	-3.000
c_x	0.000	0.000	0.000
s_w	0.000	0.034	0.468
ω_x	0.400	0.372	0.400
ω_d	0.700	0.700	0.699
a_{xd}	0.189	0.250	0.202
a_{dx}	0.250	0.500	0.250
m_x	0.250	0.237	0.170
m_d	0.082	0.196	0.032
i	0.070	0.012	0.028
ρ_K	0.000	0.003	pre-'97 0.081 post-'97 0.048

Discussion

In this paper we have described the development and calibration of a structuralist model for small island developing states (SIDS), which we applied to the Caribbean countries of Barbados, Jamaica, and Trinidad and Tobago. The model design seeks to capture insights from the Caribbean economic tradition while acknowledging data limitations. We accomplished this by building on that tradition, taking a dual-sector model and constructing an effective one-sector model. This allowed us to calibrate the model against mainly external data, while relating it to an implicit internal structure. For the most part, the estimated parameter values make sense, and the goodness-of-fit statistics are largely supportive of the model.

To the extent that the estimated parameters reflect reality, they yield a positive result about the three economies. A central concern in Caribbean economic thought (emphasized by Demas 2009 [1965]) is the degree to which the export sector – the source of foreign exchange and the engine of growth – is inserted into the domestic economy. In the model this insertion is reflected in the input-output coefficients a_{dx} and a_{xd}. These are significantly positive (the bottom end of the 95% confidence interval is greater than zero), indicating substantial intermediate exchange between the domestic and export sectors.

The statistical results are also encouraging. The structural features of the Caribbean islands arise from their small size and access to export markets. These features are common to all SIDS, and so is the reality of limited data. This suggests that the model and methods used in this paper can be extended to other SIDS contexts. Nevertheless, the results must be treated with considerable caution until they have been validated, and the models refined, using data within the countries.

Best practice in systems dynamics modeling is to estimate parameters using data below the level of aggregation of the model (Graham 1976, 549). Parameters such as domestic consumption of goods from the export sector, c_x, basic consumption expenditure c_0, and import propensity m can be estimated from household surveys, while consumption of intermediate goods (both domestic and imported) can be estimated from industry surveys and intermittent national statistics. The fundamental assumptions (e.g., the form of the consumption function) can be further tested through surveys. While these data may be available only at one or two times, rather than as a series, they bound the possible range of model parameters and can suggest refinements to the model. Using within-country data, the model can be extended to include domestic activities and the internal balance, including banking, taxation and the government sector.

The model was developed to support a set of Caribbean climate adaptation scenarios (Drakes et al. 2016). At present, the economic models used for climate policy are best suited to large continental economies. Even in this context, they are problematic (Stanton, Ackerman, and Kartha 2009), but by design they are a poor fit to small open economies. Yet, SIDS are particularly vulnerable to climate change (Nurse et al. 2014), so there is a need for models that are well adapted to the realities that SIDS face. As noted by Kraay and Easterly (1999), as a group small open economies, including SIDS, have relatively high per capita incomes compared to countries in the same region. Kraay and Easterly conclude from this that the problems of SIDS and other small states are "small", but we disagree. In addition to climate vulnerability, SIDS are vulnerable to global and regional economic conditions. They rely for their growth on fickle export markets and for their development on successfully integrating their export and domestic markets. This is not a problem that is solved once and for all, and many of the drivers of change are outside of the country's direct control. Economic models used for policy analysis should account for these facts.

Conclusion

This paper presents a model for small island developing states (SIDS) in the Caribbean structuralist tradition. Growth is driven by export demand, while development, in Demas' (2009 [1965]) terms, is dependent on the integration of the export sector with the rest of the domestic economy. Starting with a two-sector model (domestic and export), we constructed an effective one-sector model and calibrated it for Barbados, Jamaica, and Trinidad and Tobago using components of the external balance, aggregate national accounts, price series, and population.

The results are encouraging. The parameter estimates and goodness-of-fit statistics are, for the most part, reasonable, suggesting that the model is capturing real features of Caribbean economies. The model is intended for use in climate adaptation scenarios, but should be further validated and informed using within-country data. If it proves to be realistic and useful then it should be suitable for other SIDS, both inside and outside the Caribbean.

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