

Analyzing Country Strategies for Structural Transformation, Poverty Eradication and Shared Prosperity: Method and Application to an Archetype SSA Country

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Abstract

Many developing countries view export-oriented structural transformation as offering the most promising path toward accelerated growth, poverty reduction, and shared prosperity. This paper develops an approach to medium- and long-run analysis of policies and other aspects of

such a transformation. The approach integrates elements of product-space (PS) analysis with CGE modeling. In this pilot study, the approach is applied to an archetype SSA country and used to analyze the impact of alternative export market conditions and government policies on growth, sector structure, poverty, and shared prosperity.

The analysis uses the core version of MAMS (Maquette for Millennium Development Goal Simulations), a recursive-dynamic CGE model, augmented to incorporate the following PS features: (a) proximity between sectors influences loss in labor effectiveness from reallocation; (b) proximity-weighted learning-by-doing, driven by accumulated production, influences activity TFP; and (c) penetration of export markets may lead to quality upgrading and higher export prices. Against this background, the model is referred to as the core version of MAMS-PS.

The augmentation of the model to cover PS features requires a parallel augmentation of the database, including (a) a global matrix of proximities between sectors based on export data for tradable goods sectors and value-added data for other sectors; (b) country- and sector- specific data on distance of base-year export prices from the frontier of unit prices (the prices received top-quality exporters); and (c) econometric estimates of the determination of country-level deviations from average unit export prices. In simulations, broad goods sectors are identified as promising for targeted policies on the basis of the findings from stand-alone PS analysis by Hausmann et al. (2014). Our results show that policy incentives (via taxes, subsidies and/or public investment) in favor of promising sectors may have significant positive effects (in terms of growth, poverty reduction, and reduced inequality). Conversely, incentives in favor of sectors that lack these characteristics have opposite effects. Such results may be negated by adverse world price changes for promising sectors.

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1. Introduction

Many countries in Sub-Saharan Africa (SSA) are striving to identify strategies for structural transformation that bring about rapid growth with exports playing an important role, often with the aim of achieving middle-income status within the next few decades. This paper develops an innovative approach to the analysis of such strategies and applies it to an archetype SSA country. The approach augments a Computable General Equilibrium (CGE) model by incorporating indicators from product-space (PS) analysis that influence the extent and consequences of changes in sector structure. In this case, the CGE model is an augmented version of MAMS (Maquette for MDG Simulations), a CGE model for country-level strategy analysis. The model is used to simulate the effects of changes in policies and world markets on macro, sector, and welfare indicators. More specifically, this study provides a forward-looking perspective with the aim of identifying strategies for structural transformation that, during the next two decades, promise to further reduce poverty, enhance shared prosperity, and accelerate growth in production, incomes, and employment.

We proceed as follows. Section 2 describes the model and its disaggregation, with a focus on the PS-related extensions. Section 3 covers the base run and a set of scenarios that focus on policy changes related to structural transformation and aspects of the external environment that condition the effects of these policy changes. The concluding Section 4 extracts the implications of the preceding analysis for country development strategy and discusses a future research agenda.

Appendices provide additional background and details: Appendix A reviews key concepts of product-space analysis; B derives the first-order conditions for producer profit maximization in MAMS in a PS context, including their derivation; C-D presents additional data related to the model database and the simulations, respectively.

2. Method: Bringing product-space into a CGE model

The starting point for our development of a CGE model with PS features is the core (non-MDG) version of MAMS, which has the advantage of covering a wide range of policies and indicators of interest to long-run strategy analysis in low-income countries (including endogenous productivity growth and a built-in poverty module). The fact that it, as opposed to the MDG version of MAMS, does not endogenize human development permits a more focused analysis of issues related to structural transformation and the new PS features.¹ In this section, we provide a non-technical overview of the core MAMS model, including its disaggregation for this study, as well as technical detail on the PS-related extensions.

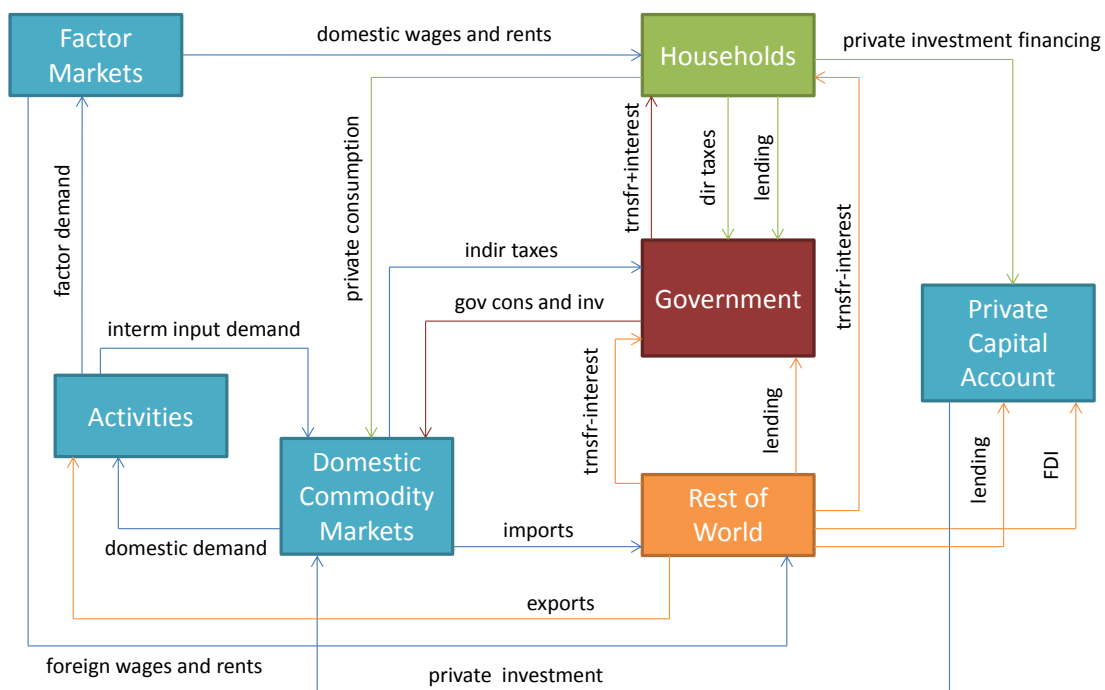
Model structure and database

The core version of MAMS

As indicated by Figure 2.1, which serves as the reference point for our model overview, the major building blocks of MAMS are activities (the entities that carry out production), commodities (activity outputs or, exceptionally, imports without domestic production; linked to markets), factors (also linked to markets), and institutions (households, the government, and the rest of the world). In the figure, the private capital account also has its own box given the multiple links that exist between private investment demands and their financing. In any MAMS application (and dataset), most blocks are disaggregated – the disaggregation in the SSA country MAMS application is shown in Table 2.1.

¹ For more on MAMS, see Lofgren et al. (2013), Bourguignon et al. (2008). The website www.worldbank.org/mams provides links to a wide range of documents and applications. At a later stage, it would clearly be appropriate to consider human development questions in the context of analyses of strategies for structural transformation.

Figure 2.1. Overview of MAMS



Source: Authors' calculations.

Table 2.1: Disaggregation of archetype SSA country MAMS application and SAM

Category - #	Category	Item	Category - #	Category	Item
Sectors (activities and commodities) (29)	Agriculture (3)	Agriculture	Factors (12)	Private (5)	Labor
		Forestry			Private capital
		Fishing			Land
	Mining (2)	Petroleum and gas			Timber
		Mining			Fish
	Manufacturing (13)	Food			Extractive res in Pet and gas
		Beverages			Extractive res in Mining
		Tobacco product			
		Textiles and leather	Government (7)		Gov cap other gov services
		Wood			Gov cap infra agriculture
		Paper			Gov cap infra transport
		Refined petroleum products			Gov cap infra energy
		Chemical products			Gov cap infra other
		Rubber and plastic	Institutions (12)	Current accounts	Households
		Non-metalic mineral products			Government
		Metal products			Rest of the world
		Machinery and vehicles		Auxiliary accounts	Taxes on production
		Other manufactures			Taxes on sales
	Private services (6)	Electricity and gas			Taxes on imports
		Construction			Taxes on income
		Trade, hotels and restaurants			Interest, domestic
		Transport			Interest, foreign
		Communications		Capital accounts	Households
		Other services			Government
	Government services (5)	Other government services			Rest of the world
		Gov infra agriculture	Investment (7)	Fixed	Private (non-government)
		Gov infra transport			Gov other gov services
		Gov infra energy			Gov infra agriculture
		Gov infra other			Gov infra transport
					Gov infra energy
					Gov infra other
				Stock change	Private (non-government)

Source: Authors' summary of archetype SSA country MAMS-PS database.

In any single year, archetype SSA country MAMS has the structure summarized in the above figure. Activities produce, selling their output at home or abroad, and using their revenues to cover their costs (of intermediate inputs, factor hiring and taxes). Their decisions to pursue particular activities with certain levels of factor use are driven by profit maximization. The

shares exported and sold domestically depend on the relative prices of their output in world and domestic markets.

Archetype SSA country MAMS includes three types of institutions: households, government, and the rest of the world. Households earn incomes from factors, transfers and interest from the government (with the interest due to loans from the households to the government), and transfers from the rest of the world, net of interest on household foreign debt, if any. These incomes are used for direct taxes, savings, and consumption. The savings share depends on per-capita incomes. Their consumption decisions change in response to income and price changes. By construction (and as required by the household budget constraints), the consumption value of the households equals their income net of direct taxes and savings.

The government gets its receipts from taxes and transfers from abroad; it uses these for consumption, transfers to households, and investment (providing the capital stocks required for producers of government services), drawing on domestic and foreign borrowing for supplementary investment funding. To remain within its budget constraint, it either adjusts some part(s) of its spending on the basis of available receipts or mobilizes additional receipts of one type or more in order to finance its spending plans; in the base scenario of the current analysis, the government adjusts foreign borrowing in order to stay within its budget constraint. (The rules for the government budget in non-base simulation are discussed in the simulation section.)

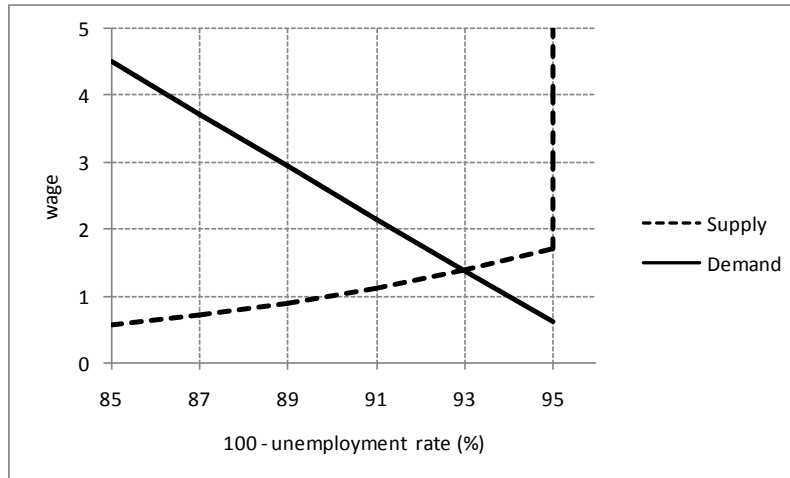
The rest of the world (which appears in the balance of payments) sends foreign currency to the model country in the form of transfers to its government and households (net of interest payments on their foreign debt stocks), FDI, loans, and export payments. The model country uses these inflows to finance its imports. The balance of payments clears (inflows and outflows are equalized) via adjustments in the real exchange rate (the ratio between the international and domestic price levels), influencing export and import quantities and values in foreign currency. Private investment financing is provided from domestic private savings (net of lending

to the government) and foreign direct investment (FDI). For the base scenario, domestically financed private investment and FDI are both exogenous shares of GDP.

In domestic commodity markets, flexible prices ensure balance between demands for domestic output from domestic demanders and supplies to the domestic market from domestic suppliers. The part of domestic demands that is for imports faces exogenous world prices – the model country is viewed as small in world markets without any impact on the import and export prices that it faces. Domestic demanders decide on import and domestic shares in their demands on the basis of the relative prices of commodities from these two sources. Similarly, domestic suppliers (the activities) decide on the shares for exports and domestic supplies on the basis of the relative prices received in these two markets.

Factor markets reach balance between demands and supplies via wage (or rent) adjustments. Across all factors, the factor demand curves are downward-sloping reflecting the responses of production activities to changes in factor wages. On the supply side of the labor markets, unemployment is endogenous – for each labor type, the model includes a wage (or supply) curve that is upward-sloping until full employment is reached, at which point it becomes vertical (see Figure 2.2; its supply curve assumes a minimum unemployment rate, in the figure at 5%). For non-labor factors, the supply curves are typically vertical (in any single year), in effect fixing total employment.

Figure 2.2: labor market specification



On the basis of simulation results for real consumption per capita for the different model households, MAMS computes indicators for poverty (the different Foster-Green Thorbecke measures), inequality (the Gini coefficient), and shared prosperity (defined on the basis of the incomes of the bottom 40 percent). The computations are based on a simple micro simulation approach in which each model household – one in our case – is mapped to a subset of the observations in a household survey. In each simulation, the changes in per-capita consumption for each model household are passed on to the mapped survey observations, assuming that the observed initial distribution within each household group is unchanged. At the same time, the mapped survey households are reweighted on the basis of simulated changes in the population shares of each model household.

The above discussion refers to the functioning of the model economy in a single year. In MAMS, growth over time is endogenous. The economy grows due to accumulation of capital (determined by investment and depreciation), labor (determined by share of the population in labor force age, the labor force participation rate, and the distribution of labor across different types, typically educational levels), other factors (on the basis of exogenous supply growth), and improvements in total factor productivity (TFP). Apart from an exogenous component, the

TFP of any production activity potentially depends on the levels of government capital stocks, economic openness and, as discussed below, a learning-by-doing component that is part of the PS features of the model.

MAMS extensions for PS analysis

MAMS is extended to incorporate key insights from PS analysis regarding factors that influence the ease or difficulty with which sector structure can evolve over time. (Appendix A defines the product-space indicators to which we refer in the main body of the text.) The aim is to use MAMS to project future medium- to long-run patterns of change in sector structure and other major indicators under alternative policies and external environments. Specifically, the following mechanisms are built into the model:

(a) Proximity-based labor reallocation.² The *proximity* indicator ($0 \leq \varphi_{a,a',t} \leq 1$) reflects the central insight of PS analysis: competitive production in one activity requires capabilities that

² For private capital, new investment is typically allocated across activities so that the capital marginal value product (MVP) is equal across activities. An exception to this rule, captured by the following constraint, is permitted to ensure that installed capital is not reallocated – in general, such reallocation is not feasible:

$QF_{a,t} \geq (1 - depr) QF_{a,t-1}$ where QF = private capital employment; $depr$ = depreciation rate for private capital; and a and t refer to production activities and time, respectively. If this constraint is binding for an activity a in t , the activity does not receive new investment and its capital rent (equal to its MVP) is scaled to fall below the capital rent in other activities. In GAMS, a mixed-complementarity relationship is programmed to impose this condition. (As a further twist, the preceding statement about the decline of the constraint activity rent below that of other activities would not necessarily hold if the model, whenever this constraint is non-binding, instead of imposing uniform capital rents imposes exogenous ratios between rents in different activities. In this setting, an activity with a binding constraint and a reduced rent relative to the ratio vis-a-vis other activities may still receive a rent that is above that of at least some other activities.)

are more or less close to the capabilities associated with other activities; it is relatively easy (difficult) to expand an activity if other activities with similar capabilities represent a large (small) share of internationally competitive production. In order to capture the implications of this insight in MAMS, we distinguish between effective and physical labor employment. In each period, physical labor quantities are associated with activities of origin, a' , on the basis of previous employment. In the model treatment of labor reallocation, the raw proximity indicator ($\varphi_{a,a',t}$) is replaced by a scaled parameter ($0 \leq \varphi_{a,a',t}^{scal} \leq 1$), with the scaling defined as part of an informal validation procedure.³ Effective employment in the activity of destination, a , falls short of the physical quantity that is reallocated from a' to a whenever labor reallocation occurs between two activities a' and a for which $\varphi_{a',a,t}^{scal} < 1$. The following equation, with subscripts for labor type and time suppressed, defines the relationship between effective and physical labor quantities:

$$QF_a = \sum_{a'} \varphi_{a',a}^{scal} \cdot QFR_{a',a}$$

(2.1) $\left[\begin{array}{l} \text{effective quantity} \\ \text{employed in } a \end{array} \right] = \left[\begin{array}{l} \text{sum of physical quantites re-} \\ \text{allocated from any } a' \text{ to } a \text{ times} \\ \text{the scaled proximity between } a' \text{ to } a \end{array} \right]$

³ Note that, for the special case with $a' = a$ (factor is “reallocated” to the same sector), $\varphi_{a',a} = 1$. The scaled *proximity* parameter is derived from the original *proximity* parameter using the following formula:

$\varphi_{a',a}^{scal} = \varphi_{a',a} + \varphi^{scal} \cdot (1 - \varphi_{a',a})$, where φ^{scal} = factor-specific scaling parameter. To ensure that $0 \leq \varphi_{a,a',t}^{scal} \leq 1$, it should satisfy the following restriction: $-\varphi_{a,a',t} / (1 - \varphi_{a,a',t}) \leq \varphi^{scal} \leq 1$. Note that

$\lim_{\varphi^{scal} \rightarrow 1} (\varphi_{a',a} + \varphi^{scal} \cdot (1 - \varphi_{a',a})) = 1$. If the non-scaled proximities are too low, simulated factor reallocation falls short of what is observed in practice; to make reallocation easier, the value of the scaling parameter should be within the following range: $0 < \varphi^{scal} \leq 1$.

where

QF_a = effective quantity employed in destination activity a

$\phi_{a',a}^{scal}$ = scaled *proximity* between the activities a'

$QFR_{a',a}$ = physical labor quantity reallocated from a' to a

This formulation is embedded in the first-order conditions for profit-maximizing producer decisions and economywide constraints for factor markets.⁴ The assignment of physical labor quantities by activity of origin is based on activity employment shares in a weighted average of recent years.⁵ *Ceteris paribus*, as a result, destination activities prefer (and are willing to pay a higher wage to) labor belonging to activities that are close (with the top priority being attached

⁴ This *proximity*-based factor reallocation treatment is inspired by Dantzig's transportation model, in which the total cost of transporting a set of items from supply to demand depots is minimized subject to demand and supply constraints (Dantzig 1963, pp. 35-42). In our version, the unit transportation costs are replaced by effective employment losses driven by PS *proximity* measures.

⁵ If only the shares of the last year are used, then the effective employment loss would only be imposed in a single year. By using a weighted average of a series of recent years, it is possible to gradually reduce effective employment losses over time, mimicking a process of more gradual learning by doing.

to labor that already belong to the destination activity).⁶ Reallocation between very distant activities is discouraged as the loss in effective quantity employed would be larger.⁷

Given that goods and service activities operate in the same labor markets, it is necessary to extend the *proximity* measures to cover sectors (activities and related commodities) that are not covered by Comtrade (a subset of the goods sectors and all service sectors). Both in SSA and elsewhere, the outputs of non-Comtrade sectors tend to be less tradable than Comtrade sectors, as manifested in relatively low export/output and import/demand ratios. If the outputs of a sector are relatively non-tradable, export data do not provide a good measure of RCA (the standard capability indicator in PS analysis) or *proximity* (in capabilities); for sectors without exports, it is obviously not possible to measure proximity or capability in this way. Given their availability and the fact that they conceptually seem more appropriate, we turn to value-added data to generate RCA and *proximity* indicators for non-Comtrade sectors, thereby ensuring exhaustive sector coverage. Thus, we view non-Comtrade sectors as constituting an integral part of the sectoral structure, both in their own right and by making different paths of structural transformations more or less difficult for Comtrade sectors. In fact, this treatment addresses a shortcoming of PS analysis: it may often be misleading to analyze strategies for

⁶ The similar result that workers already in place in a firm receive a higher wage is also generated by labor market insider-outsider theories, albeit due to largely different reasons -- labor turnover costs among which lower productivity (due to absent skills) is only one part (cf. Lindbeck, Assar, and Dennis J. Snower. 1988. *The Insider-Outside Theory of Employment and Unemployment*. MIT Press.)

⁷ The proximity approach to the modeling of imperfect labor mobility could also be applied to other factors. Instead of relying on proximity data from PS analysis, the ease with which labor or other factors is able to move between activities could be based on other data, possibly with asymmetric proximities between activities. (For example, a move from activity A to activity B may be easier than a move from B to A.)

structural transformation without considering the role of services or other sectors not covered by Comtrade.

(b) Capability accumulation. Sectoral capabilities, which evolve over time (typically but not necessarily getting stronger) are posited to influence sectoral TFPs. This is the basic insight of an extensive literature; see for example Lall (1992), Bell and Pavitt (1996), Fagerberg et al. (2010), and McMillan and Rodrik (2011). In the model, the capability of a sector a is defined on the basis of the accumulated, proximity-weighted, non-depreciated VA in all sectors a' (including a), weighted by their proximity to a . Mathematically,

$$(2.2) \quad QVAACC_{a,t} = QVAACC_{a,t-1} (1 - deprqvaacc_a) + QVA_{a,t-1}$$

$$\left[\begin{array}{c} \text{accumulated} \\ \text{value added} \\ \text{for } a \text{ in } t \end{array} \right] = \left[\begin{array}{c} \text{accumulated value added} \\ \text{for } a \text{ in } t-1 \text{ adjusted} \\ \text{for depreciation} \end{array} \right] + \left[\begin{array}{c} \text{value} \\ \text{added for} \\ a \text{ in } t-1 \end{array} \right]$$

$$(2.3) \quad QCPBLT_{a,t} = \sum_{a' \in A} \left(\frac{\phi_{a,a',t}}{\sum_{a'' \in A} \phi_{a,a'',t}} \right) QVAACC_{a',t}$$

$$\left[\begin{array}{c} \text{capability} \\ \text{in activity } a \end{array} \right] = \left[\begin{array}{c} \text{sum of proximity-weighted} \\ \text{accumulated value added in} \\ \text{any activity } a' \text{ (including } a \text{)} \end{array} \right]$$

where

$QVAACC_{a,t}$ = (non-depreciated) accumulated value added in activity a in time t

$deprqvaacc_a$ = depreciation rate for accumulated value added in activity a

$QCPBLT_{a,t}$ = capability in activity a in time t

For each activity, total factor productivity (TFP) is defined in a constant-elasticity relationship that includes, as one of its terms the ratio between the non-base and base values for

$QCPBLT_{a,t}$:

$$(2.4) \quad \alpha_{a,t} = \left(\frac{QCPBLT_{a,t}}{QCPBLT_{a,t}^0} \right)^{\varepsilon_{a,cpblt}} \prod_z \left(\frac{tfpdet_{a,z,t}}{tfpdet_{a,z,t}^0} \right)^{\varepsilon_{a,z}}$$

where

z = index of other efficiency determinants (aggregate openness to foreign trade and public capital stocks)

t = time periods

$\alpha_{a,t}$ = efficiency of activity a in time t

$QCPBLT_{a,t}^0 = QCPBLT_{a,t}$ at base scenario

$tfpdet_{a,z,t}$ = value for determinant z in time t

$tfpdet_{a,z,t}^0 = tfpdet_{a,z,t}$ at base scenario

$\varepsilon_{a,cpblt}, \varepsilon_{a,z}$ = elasticity of efficiency of in activity a with respect to z or $cpblt$ (capability)

Thus, according to this treatment, for any activity a , the accumulation of VA in the activity itself and other activities (weighted by their proximities to a) generate a stock of capability with a positive impact on TFP; the size of the impact depends on activity-specific elasticities. Like a capital stock, the capability stock is subject to depreciation; one would expect the depreciation rate to be higher for sectors with rapid technological change (Pavitt 1984).

Above, it is worth noting that the capability and the TFP for an activity a may increase as the result of accumulation past VA not only in a itself but also in other activities; the importance of the latter is determined by their proximities to a .

(c) Endogenous world export prices. An increase in export prices relative to the market average represents an additional potential mechanism in favor of structural transformation: as a country gains experience as a successful exporter, it is likely that it will be able to increase the prices it charges for a given export relative to the average world market price. The strength of this mechanism is likely to vary across sectors, being stronger for manufactures than agricultural products. For evidence of this phenomenon, see Hausmann, Hwang, and Rodrik (2007, pp. 13-14). In MAMS-PS, for all or a subset of the sectors, the world price of exports is a logistic function of export growth and GDP per capita growth relative to the base scenario.⁸ In what follows, we show the most relevant equations related to the modeling of the (endogenous) evolution of the share that the modeled country receives of the of its “highest possible” world export price.

$$(2.5) \quad PWE_{c,t} = SHPWE_{c,t} pwemax_{c,t}$$

$$\left[\begin{array}{c} \text{export price for} \\ \text{commodity } c \\ \text{in time } t \text{ (FCU)} \end{array} \right] = \left[\begin{array}{c} \text{endogenous share} \\ \text{of maximum} \\ \text{potential price} \end{array} \right] \cdot \left[\begin{array}{c} \text{maximum} \\ \text{potential} \\ \text{price} \end{array} \right]$$

⁸ In fact, according to the finding of Schott (2004), Hummels and Klenow (2005) and Henn et al. (2013), export prices are positively related to GDP per capita. Inclusion of this second determinants permits more nuanced outcomes: high export volumes at prices that are not very high and high prices in spite of volumes that are not very high (for example, shirt exports by low- and high-income countries, respectively).

$$\begin{aligned}
(2.6) \quad & \left[\begin{array}{l} \text{share of} \\ \text{maximum} \\ \text{potential price} \end{array} \right] = \left[\begin{array}{l} \text{maximum} \\ \text{share} \\ \text{value} \end{array} \right] + \left[\begin{array}{l} \text{logistic function} \\ \text{of intermediate} \\ \text{variable } ZSHPWE \end{array} \right] \\
& \left[\begin{array}{l} \text{intermediate} \\ \text{variable} \\ ZSHPWE \text{ in } t \end{array} \right] = \left[\begin{array}{l} \text{constant-elasticity function} \\ \text{of export quantity relative to base} \\ \text{year in } t-1 \text{ and GDP per capita} \\ \text{relative to base year in } t \end{array} \right]
\end{aligned}$$

$$\begin{aligned}
(2.7) \quad & ZSHPWE_{c,t} = \alpha_{c,t}^{pwecce} \left(\frac{QE_{c,t-1}}{QE_{c,t-1}^0} \right)^{\phi_{c,qe}^{pwe}} \left(\frac{GDPREALPC_t}{GDPREALPC_{tmin}} \right)^{\phi_{c,gdppc}^{pwe}}
\end{aligned}$$

where

$SHPWE_{c,t}$ = share received of benchmark (max) world export price $pwemax_{c,t}$

$ZSHPWE_{c,t}$ = intermediate variable in logistic function defining $SHPWE_{c,t}$

$PWE_{c,t}$ = (world) price of exports (FCU)

$pwemax_{c,t}$ = value for $PWE_{c,t}$ for frontier exporters

$QE_{c,t}$ = quantity of exports of c

$QE_{c,t}^0 = QE_{c,t}$ for base scenario

$GDPREALPC_t$ = real GDP per capita

$GDPREALPC_t^0 = GDPREALPC_t$ for base scenario

In addition, in equation (2.5.) $SHPWE_{c,t}$ may optionally be replaced by $SHPWE2_{c,t}$, defined in equation (2.8) in such a way that the analyst can control the extent to which "share" of $pwemax$ is "sticky" upwards, i.e. the ease with which it may decline below its past maximum share due to weaker export performance in more recent years. Of course, (exogenous) $pwemax$ can increase.

$$(2.8) \quad SHPWE2_{c,t} = wtshpwemax_{c,t} SHPWEMAX_{c,t} + (1 - wtshpwemax_{c,t}) SHPWE_{c,t}$$

where

$SHPWE2_{c,t}$ = variable replacing $SHPWE_{c,t}$ in (2.5)

$SHPWEMAX_{c,t}$ = the maximum simulated value for $SHPWE_{c,t}$ in any time period t

$wtshpwemax_{c,t}$ = weight for $SHPWEMAX_{c,t}$ in definition of $SHPWE2_{c,t}$

Note that, for $wtshpwemax_{c,t} = 1$, $SHPWE2_{c,t} = SHPWEMAX_{c,t}$ whereas for $wtshpwemax_{c,t} = 0$, $SHPWE2_{c,t} = SHPWE_{c,t}$. ($SHPWEMAX_{c,t}$ is defined in an additional model equation, not shown here.)

The three augmentations of the CGE model from the PS literature differ in their effects on the ease of transforming production structure. Efficiency losses in the context of labor reallocation make structural change more difficult. On the other hand, productivity changes due to capability accumulation (a form of learning by doing) may reinforce structural change in favor of one or more related activities once the process is under way. Finally, the change in world export prices may also favor the expanding sectors. The model is designed to capture any influence of policy makers on these processes via investments, subsidies and taxes. Such policies may have a positive impact on GDP growth and other indicators if they promote (or reduce discrimination against) activities that contribute to stronger growth in VA and incomes.

Database

The bulk of the dataset is for the simulation base-year – a social accounting matrix (SAM); stocks and sectoral employment levels for production factors (including different types of labor and capital), population split into working and non-working age, and poverty and inequality data by household group – as well as a set of elasticities (for production, consumption, trade, and human development relationships) and a baseline projection for growth in GDP at factor cost. (See Appendix C for more details.)

Like other CGE models, MAMS uses a base-year SAM (in this case for FY 2010), to define base-year values for the bulk of the model parameters, including production technologies, sources of commodity supplies (domestic output or imports), demand patterns (for household and government consumption, investment and exports), transfers between different institutions, interest rates, and tax rates. Most features of a SAM for MAMS are familiar from SAMs used for other models. However, a MAMS SAM has some unconventional features related to the explicit treatment of financial flows. The disaggregation of the archetype SSA country SAM coincides with that of the rest of the model database. As shown in Table 2.1, it is disaggregated into 29 sectors (activities and commodities) – 3 in agriculture, 2 in mining, 13 in manufacturing, and 11 in services – with each activity producing a single commodity for which it is the only domestic producer. The factors are split into labor, capital (one private and one for each government service sector), and natural resources (5 types: agricultural land, forestry land, fishing resources, and two natural resources used in extractive industries). The institutions are split into households, government, and the rest of world, each of which has current and capital accounts. A set of auxiliary accounts cover the different tax instruments as well as domestic and foreign interest payments.

On the basis of SAM data, Table 2.3 summarizes the sectoral structure of archetype SSA country's economy in FY2010: sectoral shares in value-added, production, employment, exports and imports, as well as the split of domestic sectoral supplies between exports and domestic

sales, and domestic sectoral demands between imports and domestic output. For instance, while (primary) agriculture represents a significant share of employment (around 66 percent), its shares of value added (VA), production, and exports are much smaller (in the range of 15-25 percent).⁹ The share of its output that is exported is around 10 percent while only some 5 percent of domestic demands are met via imports.

⁹ The sectoral structure according to the national accounts (regularly published by UBOS) and the 2009/10 Supply and Use Tables are not fully consistent: for example, according to former, the share of agriculture in GDP was 17.5% in 2009/10 while, according to the latter, it was 24.4%.

Table 2.3: Sectoral structure of archetype SSA country's economy in FY 2010
(percent)

Sector	VAshr	PRDshr	EMPshr	EXPshr	EXP- OUTshr	IMPshr	IMP- DEMshr
Agriculture	24.6	15.9	66.0	21.8	10.2	4.7	4.8
Forestry	4.6	3.1	1.2	0.0	0.1	0.0	0.1
Fishing	1.3	0.8	0.2	4.0	33.0	0.0	0.4
Petroleum and gas	0.1	0.1	0.0	0.0	0.1	0.0	0.1
Mining	1.1	1.1	0.3	0.7	3.5	1.5	16.8
Food	7.2	11.3	3.1	12.9	9.0	7.1	10.5
Beverages	0.9	1.7	0.2	2.9	13.3	1.2	15.9
Tobacco product	0.1	0.2	0.0	0.3	15.1	0.2	41.6
Textiles and leather	1.0	1.0	0.3	8.6	56.4	5.0	65.2
Wood	0.0	0.5	0.0	0.4	6.5	0.2	5.7
Paper	0.1	0.1	0.0	0.6	30.9	2.0	75.2
Refined petroleum products	0.0	0.1	0.0	0.5	41.3	16.2	98.8
Chemical products	1.1	1.3	0.2	3.2	17.2	11.3	59.6
Rubber and plastic	0.2	0.2	0.0	1.0	33.3	2.1	69.3
Non-metalic mineral products	0.8	1.2	0.1	3.2	20.3	2.7	29.7
Metal products	0.8	1.3	0.1	5.6	34.7	8.3	59.0
Machinery and vehicles	0.1	0.2	0.0	0.7	14.1	26.5	96.2
Other manufactures	0.6	1.0	0.1	0.9	7.3	1.9	25.1
Electricity and gas	0.5	0.4	0.2	0.5	10.4	0.1	4.6
Construction	6.6	11.3	3.2	0.0	0.0	0.0	0.0
Trade, hotels and resturants	14.9	17.2	7.2	16.2	8.3	2.1	1.9
Transport	2.5	2.3	1.2	2.9	10.9	3.9	21.4
Communications	3.7	3.6	1.0	0.0	0.0	0.0	0.0
Other gov services	3.2	3.3	2.7	0.0	0.0	0.4	1.8
Gov infra agriculture	0.1	0.1	0.0	0.0	0.0	0.0	2.2
Gov infra transport	0.3	0.4	0.3	0.0	0.0	0.1	2.2
Gov infra energy	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Gov infra other	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Other services	23.8	20.3	12.1	13.0	5.7	2.5	1.8
Total	100.0	100.0	100.0	100.0	7.8	100.0	16.0

References: VAshr = value-added share (%); PRDshr = production share (%); EMPshr = share in total employment (%); EXPshr = sector share in total exports (%); EXP-OUTshr = exports as share

in sector output (%); IMPshr = sector share in total imports (%); IMP-DEMshr = imports as share of domestic demand (%).

Source: Authors' calculations based on 2010 archetype SSA country SAM and employment data.

Table 2.4 shows the factor shares in total sectoral value added. For example, the table shows that agriculture is relatively intensive in the use of labor; this information will be useful to analyze the results from the MAMS-PS simulations.

Table 2.4: Sectoral factor intensity in FY 2010
(percent)

Sector	Labor	Prv Capital	Nat Res	Total
Agriculture	73.7	15.0	11.3	100.0
Forestry	36.0	0.3	63.7	100.0
Fishing	21.1	0.2	78.7	100.0
Petroleum and gas	27.3	38.1	34.6	100.0
Mining	27.3	51.5	21.2	100.0
Food	68.9	31.1	0.0	100.0
Beverages	23.0	77.0	0.0	100.0
Tobacco product	66.1	33.9	0.0	100.0
Textiles and leather	39.6	60.4	0.0	100.0
Wood	14.6	85.4	0.0	100.0
Paper	27.3	72.7	0.0	100.0
Refined petroleum products	9.3	90.7	0.0	100.0
Chemical products	19.2	80.8	0.0	100.0
Rubber and plastic	17.6	82.4	0.0	100.0
Non-metalic mineral products	17.4	82.6	0.0	100.0
Metal products	17.9	82.1	0.0	100.0
Machinery and vehicles	15.1	84.9	0.0	100.0
Other manufactures	30.0	70.0	0.0	100.0
Electricity and gas	41.6	58.4	0.0	100.0
Construction	50.7	49.3	0.0	100.0
Trade, hotels and resturants	49.6	50.4	0.0	100.0
Transport	48.8	51.2	0.0	100.0
Communications	19.6	80.4	0.0	100.0
Other government services	100.0	0.0	0.0	100.0
Gov infra agriculture	100.0	0.0	0.0	100.0
Gov infra transport	100.0	0.0	0.0	100.0
Gov infra energy	100.0	0.0	0.0	100.0
Gov infra other	100.0	0.0	0.0	100.0
Other services	52.9	47.1	0.0	100.0
Total	55.7	37.3	7.0	100.0

Source: Authors' calculations based on 2010 archetype SSA country SAM.

In terms of dataset, the computed PS-related proximity between all pairs of commodities is shown in Table 2.4. As explained in the Appendix A, this is the key building-block for all network indicators in the PS analysis.

Table 2.5: Proximity between sectors in the archetype SSA country SAM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1 Agriculture	1.00	0.48	0.49	0.23	0.46	0.80	0.46	0.36	0.44	0.39	0.23	0.25	0.20	0.26	0.31	0.43	0.10	0.16	0.48	0.46	0.64	0.57	0.46	0.26	0.26	0.26	0.26	0.26	0.23
2 Forestry	0.48	1.00	0.48	0.14	0.27	0.52	0.45	0.39	0.50	0.59	0.34	0.30	0.25	0.41	0.43	0.42	0.18	0.25	0.47	0.49	0.48	0.51	0.50	0.16	0.16	0.16	0.16	0.16	0.25
3 Fishing	0.49	0.48	1.00	0.22	0.39	0.51	0.54	0.49	0.46	0.37	0.29	0.22	0.24	0.27	0.34	0.31	0.17	0.27	0.34	0.43	0.46	0.32	0.40	0.32	0.32	0.32	0.32	0.32	0.32
4 Petroleum and gas	0.23	0.14	0.22	1.00	0.26	0.16	0.08	0.11	0.15	0.25	0.11	0.41	0.08	0.03	0.14	0.13	0.08	0.04	0.26	0.22	0.27	0.22	0.21	0.15	0.15	0.15	0.15	0.15	0.07
5 Mining	0.46	0.27	0.39	0.26	1.00	0.38	0.35	0.29	0.31	0.35	0.23	0.31	0.20	0.09	0.22	0.49	0.03	0.26	0.32	0.33	0.37	0.36	0.40	0.37	0.37	0.37	0.37	0.37	0.20
6 Food	0.80	0.52	0.51	0.16	0.38	1.00	0.52	0.43	0.49	0.44	0.26	0.30	0.25	0.33	0.39	0.36	0.10	0.26	0.49	0.51	0.56	0.57	0.46	0.28	0.28	0.28	0.28	0.28	0.25
7 Beverages	0.46	0.45	0.54	0.08	0.35	0.52	1.00	0.48	0.45	0.43	0.40	0.25	0.25	0.40	0.50	0.42	0.18	0.30	0.32	0.49	0.38	0.39	0.50	0.33	0.33	0.33	0.33	0.33	0.50
8 Tobacco product	0.36	0.39	0.49	0.11	0.29	0.43	0.48	1.00	0.51	0.48	0.26	0.21	0.26	0.42	0.45	0.31	0.18	0.45	0.28	0.39	0.37	0.32	0.44	0.24	0.24	0.24	0.24	0.24	0.34
9 Textiles and leather	0.44	0.50	0.46	0.15	0.31	0.49	0.45	0.51	1.00	0.38	0.21	0.28	0.21	0.38	0.49	0.38	0.08	0.36	0.36	0.39	0.40	0.44	0.38	0.13	0.13	0.13	0.13	0.13	0.18
10 Wood	0.39	0.59	0.37	0.25	0.35	0.44	0.43	0.48	0.38	1.00	0.43	0.28	0.10	0.40	0.45	0.44	0.25	0.30	0.47	0.45	0.37	0.46	0.44	0.23	0.23	0.23	0.23	0.23	0.25
11 Paper	0.23	0.34	0.29	0.11	0.23	0.26	0.40	0.26	0.21	0.43	1.00	0.18	0.22	0.48	0.43	0.36	0.41	0.26	0.26	0.33	0.23	0.27	0.33	0.37	0.37	0.37	0.37	0.37	0.55
12 Refined petroleum products	0.25	0.30	0.22	0.41	0.31	0.30	0.25	0.21	0.28	0.28	0.18	1.00	0.26	0.15	0.30	0.31	0.12	0.21	0.36	0.39	0.19	0.37	0.38	0.24	0.24	0.24	0.24	0.24	0.18
13 Chemical products	0.20	0.25	0.24	0.08	0.20	0.25	0.25	0.26	0.21	0.10	0.22	0.26	1.00	0.33	0.30	0.16	0.26	0.30	0.11	0.27	0.15	0.19	0.25	0.38	0.38	0.38	0.38	0.38	0.45
14 Rubber and plastic	0.26	0.41	0.27	0.03	0.09	0.33	0.40	0.42	0.38	0.40	0.48	0.15	0.33	1.00	0.62	0.33	0.48	0.45	0.26	0.39	0.21	0.34	0.40	0.30	0.30	0.30	0.30	0.30	0.52
15 Non-metallic mineral products	0.31	0.43	0.34	0.14	0.22	0.39	0.50	0.45	0.49	0.45	0.43	0.30	0.30	0.62	1.00	0.51	0.30	0.35	0.40	0.49	0.27	0.42	0.44	0.24	0.24	0.24	0.24	0.24	0.38
16 Metal products	0.43	0.42	0.31	0.13	0.49	0.36	0.42	0.31	0.38	0.44	0.36	0.31	0.16	0.33	0.51	1.00	0.24	0.31	0.53	0.53	0.35	0.49	0.50	0.20	0.20	0.20	0.20	0.20	0.29
17 Machinery and vehicles	0.10	0.18	0.17	0.08	0.03	0.10	0.18	0.18	0.08	0.25	0.41	0.12	0.26	0.48	0.30	0.24	1.00	0.33	0.21	0.22	0.17	0.22	0.23	0.27	0.27	0.27	0.27	0.27	0.41
18 Other manufactures	0.16	0.25	0.27	0.04	0.26	0.26	0.30	0.45	0.36	0.30	0.26	0.21	0.30	0.45	0.35	0.31	0.33	1.00	0.26	0.31	0.17	0.29	0.27	0.22	0.22	0.22	0.22	0.22	0.31
19 Electricity and gas	0.48	0.47	0.34	0.26	0.32	0.49	0.32	0.28	0.36	0.47	0.26	0.36	0.11	0.26	0.40	0.53	0.21	0.26	1.00	0.47	0.45	0.56	0.42	0.19	0.19	0.19	0.19	0.19	0.15
20 Construction	0.46	0.49	0.43	0.22	0.33	0.51	0.49	0.39	0.39	0.45	0.33	0.39	0.27	0.39	0.49	0.53	0.22	0.31	0.47	1.00	0.29	0.49	0.51	0.29	0.29	0.29	0.29	0.29	0.39
21 Trade, hotels and restaurants	0.64	0.48	0.46	0.27	0.37	0.56	0.38	0.37	0.40	0.37	0.23	0.19	0.15	0.21	0.27	0.35	0.17	0.17	0.45	0.29	1.00	0.49	0.38	0.19	0.19	0.19	0.19	0.19	0.19
22 Transport	0.57	0.51	0.32	0.22	0.36	0.57	0.39	0.32	0.44	0.46	0.27	0.37	0.19	0.34	0.42	0.49	0.22	0.29	0.56	0.49	0.49	1.00	0.47	0.20	0.20	0.20	0.20	0.20	0.19
23 Communications	0.46	0.50	0.40	0.21	0.40	0.46	0.50	0.44	0.38	0.44	0.33	0.38	0.25	0.40	0.44	0.50	0.23	0.27	0.42	0.51	0.38	0.47	1.00	0.35	0.35	0.35	0.35	0.35	0.40
24 Other government services	0.26	0.16	0.32	0.15	0.37	0.28	0.33	0.24	0.13	0.23	0.37	0.24	0.38	0.30	0.24	0.20	0.27	0.22	0.19	0.29	0.19	0.20	0.35	1.00	0.45	0.45	0.45	0.45	0.48
25 Gov infra agriculture	0.26	0.16	0.32	0.15	0.37	0.28	0.33	0.24	0.13	0.23	0.37	0.24	0.38	0.30	0.24	0.20	0.27	0.22	0.19	0.29	0.19	0.20	0.35	0.45	1.00	0.45	0.45	0.45	0.48
26 Gov infra transport	0.26	0.16	0.32	0.15	0.37	0.28	0.33	0.24	0.13	0.23	0.37	0.24	0.38	0.30	0.24	0.20	0.27	0.22	0.19	0.29	0.19	0.20	0.35	0.45	0.45	1.00	0.45	0.45	0.48
27 Gov infra energy	0.26	0.16	0.32	0.15	0.37	0.28	0.33	0.24	0.13	0.23	0.37	0.24	0.38	0.30	0.24	0.20	0.27	0.22	0.19	0.29	0.19	0.20	0.35	0.45	0.45	0.45	1.00	0.45	0.48
28 Gov infra other	0.26	0.16	0.32	0.15	0.37	0.28	0.33	0.24	0.13	0.23	0.37	0.24	0.38	0.30	0.24	0.20	0.27	0.22	0.19	0.29	0.19	0.20	0.35	0.45	0.45	0.45	0.45	1.00	0.48
29 Other services	0.23	0.25	0.32	0.07	0.20	0.25	0.50	0.34	0.18	0.25	0.55	0.18	0.45	0.52	0.38	0.29	0.41	0.31	0.15	0.39	0.19	0.19	0.40	0.48	0.48	0.48	0.48	0.48	1.00

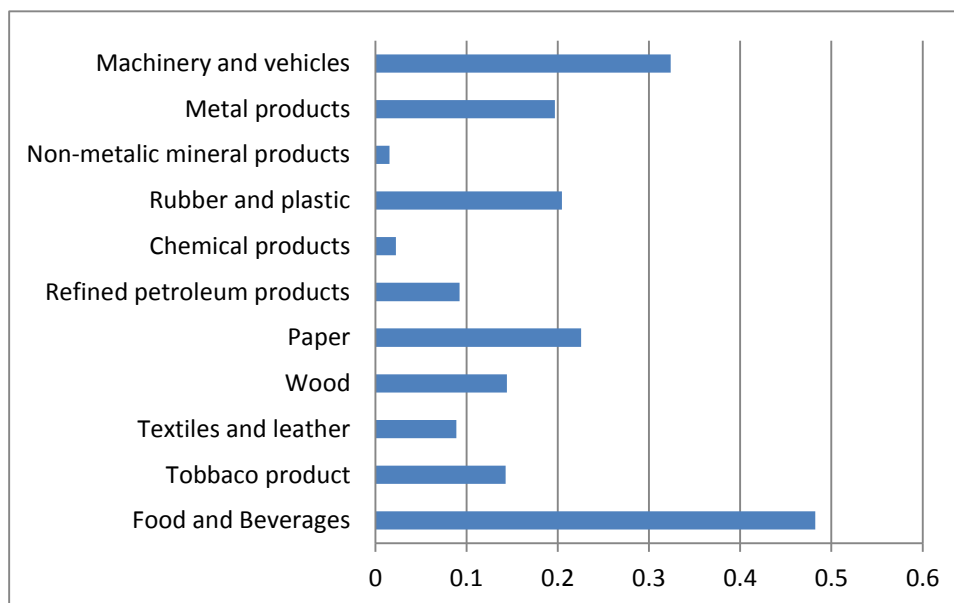
Source: Authors' calculations based on Comtrade and GTAP 8 data.

As shown in equation (2.7) above, $SHPWE$ is a function of the ratio between exports and real GDP per capita in the non-base simulation and at the base scenario, through the intermediate variable $ZSHPWE$. For calibration, we need to determine how much the archetype SSA country's exports in a given sector would have to increase to close a certain proportion of the gap between the initial price received by the model country ($PWE_{c,tmin}$) and the highest attainable world price ($pwemax_{c,t}$). Specifically, we need to provide (a) the evolution of $pwemax_{c,t}$ over time (a price projection for the frontier exporters); (b) the maximum attainable value for $SHPWE_{c,t}$ (which is indicated by the parameter $ext_{c,t}^{pwe}$; $0 < ext_{c,t}^{pwe} \leq 1$), and (c) the ratios $QE_{c,t}/QE_{c,t=0}$ and $GDPREALPC_t/GDPREALPC_{t=0}$ that would allow achieving the target value for $SHPWE_{c,t}$. The calibration of the logistic function is based on unit values (proxies for prices) and export, both extracted from a cross-country database (which covers most countries of the world) and classified at the archetype SSA country SAM sectoral level.¹⁰ Figure 2.3 shows the sectoral average ratios (i.e., the gaps) for the period 2007-2012 between the archetype SSA country export prices and the 90th percentiles of world export prices (see Appendix C for details). For the calibration process, we estimated the relation between $SHPWE_{c,t}$ and its determinants in equation (2.7) using cross-country data on export unit values, exports, and GDP per capita. In general, for commodities with a starting point that is more distant from $pwemax$,

¹⁰ In practice, there is wide variation in unit values across countries, both when measured for aggregated and disaggregated product categories. Most analysts consider quality differences as the main reason, but unit value differences may also reflect differences in production costs or pricing strategies. In addition, changes over time in unit values may reflect changes in quality-adjusted prices (owing to supply or demand shocks), rather than changes in quality (Henn et al., 2013). With regard to the last point, such changes may simply be viewed as changes in the international price for the good in question.

a larger increase in exports – relative to the base year – is needed to close a given percentage of the gap relative to the 90th percentile world price.

Figure 2.3: Average ratios between the archetype SSA country export prices and the 90th percentiles of world export prices (2007-2012)



Source: Authors' calculations based on Comtrade and CEPII data.

In terms of PS-related model elasticities, the following values were selected:

- elasticity of TFP with respect to the stock of sector-specific infrastructure = 0.15;
- elasticity of TFP with respect to capability accumulation (i.e., $\varepsilon_{a,cpblt}$ in equation (2.4) above) = 0.5; and
- elasticity of the share received of benchmark (max) world export price in constant-elasticity function (see equation (2.7) above) = 0.35.

In order to focus on structural characteristics of the economy to explain the results, the same elasticities were imposed for all sectors.

3. Simulations

In this section, MAMS-PS is used to assess the impact of alternative government policies on growth and the sectoral structure of production and employment.

Scenarios

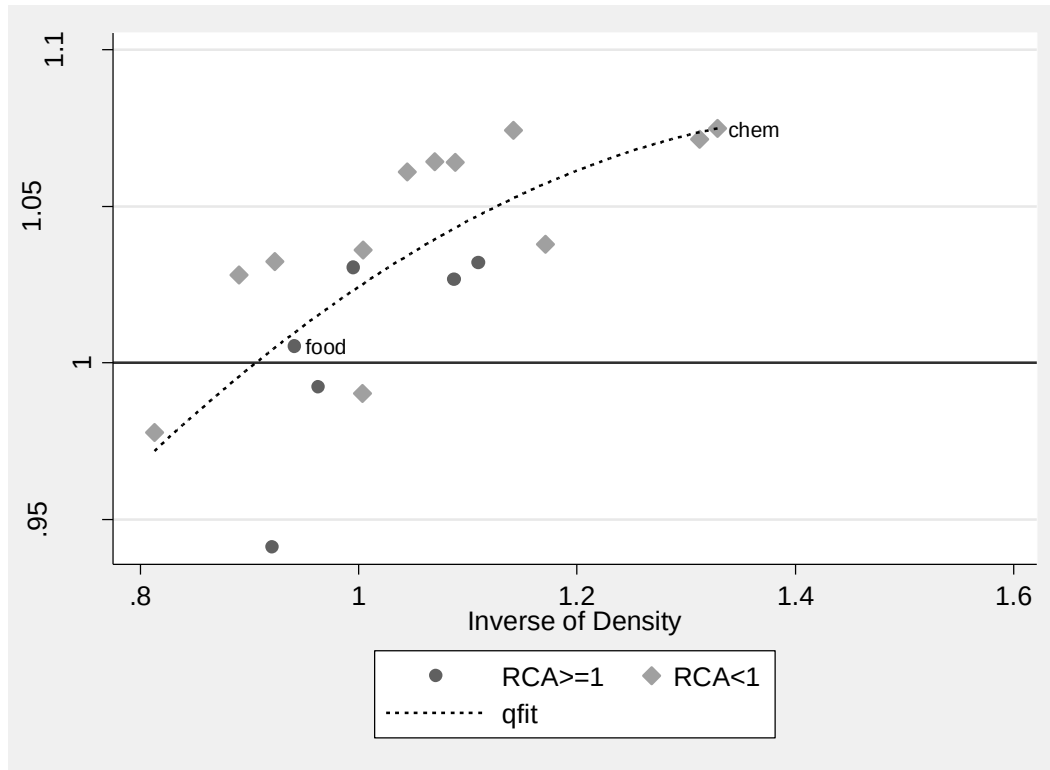
This section presents the simulations and analyzes their results. The simulations consist of a base simulation and a set of non-base simulations that explore the impact of changes in policies and exogenous conditions. The archetype SSA country MAMS simulations cover the period 2010-2030. The initial year, 2010, was selected in light of data availability (see above). The base run is designed to replicate trends since 2010 at the macro and sectoral levels. From 2013 on, this first simulation assumes that past trends will continue into the period from 2013 to 2030. In terms of PS-related indicators, their evolution in the different scenarios is endogenous.

The non-base simulations are designed to explore alternative broad strategies for sectoral transformation and how their outcomes may be affected by the extent to which archetype SSA country is successful in (1) translating accumulation of capabilities into higher productivity; (2) translating export success into higher export prices; and (3) ensuring that, in the labor market, workers are able to relocate with limited initial efficiency losses and to reach the efficiency of those who already work in the sectors to which they are reallocated.

In terms of sector prioritization, two alternatives are considered: (a) “parsimonious transformation”: the prioritized sectors are in the vicinity of the country’s current set of capabilities but that have higher sophistication, thus making the development of the new products faster and less risky (see Hausmann et al. 2013, pp. 23-24) (i.e., sectors with a PROY

larger than EXPY and a high density); and (b) “strategic bets”: the prioritized sectors are more distant from archetype SSA country’s current capabilities, more sophisticated, and of larger strategic value (i.e., sectors with even higher PRODY-EXPY difference and low density). In this analysis, food sectors are singled out under (a) while chemical sectors are singled out under (b). Thus, the “strategic bets” scenario involves using some combination of government spending on subsidies and infrastructure to promote a cluster of sectors that show high complexity or opportunity gain but lies at a greater distance from the current productive knowledge of archetype SSA country. For our archetype SSA country, the chemical sector has such characteristics. According to Hausmann et al. (2013, pp. 23-24), it is, compared to other sectors, relatively sophisticated and of larger strategic value, even if – according the PS analysis -- it lies at significantly greater distance from our archetype SSA country’s current capabilities. Figure 4.1 summarize the PS indicators for these two sectors groups.

Figure 4.1: Strategic value (*PRODY-EXPY* ratio) versus distance



Source: Authors' calculations

The following non-base scenarios have been developed to illustrate our proposed PS modeling approach, and to assess the prospects for structural change in our archetype SSA country:

- **sub-food:** 12.5% subsidy (negative activity tax) on Food during 2015-2019 with gradual reduction between 2020 and 2025; government financing through direct taxes. This scenario corresponds to a “parsimonious transformation”, where – implicitly -- the industries that are incentivized are in the vicinity of the country’s current set of capabilities but have higher sophistication, thus making the development of the new products faster and less risky (see Hausmann et al. (2013); pages 23-24).

- **inf-food:** same increase in fiscal space as sub-food with flexible investment in Food-specific infrastructure; i.e. infrastructure that increases TFP only in the said sector.
- **sub-chem:** same increase in fiscal space as sub-food with flexible subsidy (negative activity tax) on Chemical products. On average, the Chemical products sector receives a subsidy of 36.2% during 2015-2019, also with gradual reduction between 2020 and 2025. This scenario corresponds to a case of “strategic bets”, where the promoted sectors are more sophisticated and provide a larger strategic value, even if – according the PS analysis -- they lie at significantly greater distance (see Hausmann et al. (2013); pages 23-24).
- **inf-chem:** same increase in fiscal space as sub-food with flexible investment in Chemical products-specific infrastructure; i.e. infrastructure that increases TFP only in the said sector.
- **inf-mnf:** same increase in fiscal space as sub-food but assuming that the government provides infrastructure that benefits all manufacturing sectors. Thus, this scenario assesses how the results differ if the sectoral targeting is broader.

It is relevant to note that, given the assumption of a uniform tax shock (i.e., additional fiscal space is the same), our simulations are comparable in terms of magnitude of results. In addition, we test the sensitivity of our “central” simulation results to assumptions regarding MAMS PS extensions (see Section 2). Specifically, in the Appendix D we show the results of running the five scenarios described above under the following alternative sets of assumptions: (a) only proximities among sectors to reallocate labor, (b) no capability accumulation, and (c) no endogenous world export prices for selected sectors. Besides, we conducted a systematic sensitivity analysis by changing (a) elasticities in production and consumption, (b) scaled proximities among sectors, (c) TFP-related elasticities, and (d) parameters in the logistic functions that determine the evolution of sectoral world export prices.

Base scenario

The base year of the model is FY 2010, but all available information and estimates for more recent years have been taken into account. For the base scenario, which serves as a benchmark for comparisons, we impose the observed growth rates in real GDP at factor cost for the period FY 2010-2013, and an average growth of 6.7 percent during FY 2014-2025, based on projections from the IMF World Economic Outlook.¹¹ In addition, the following assumptions are imposed: (1) government demand for government services is kept fixed as a share of GDP at the base year value; (2) transfers from government to households are also kept fixed as a share of GDP; (3) tax rates are fixed over time; (4) the ratio of domestic government borrowing to GDP is kept fixed as a share of GDP at the base year value; and (5) consistent with MFPED (2013), the ratio of foreign government debt to GDP increases from 14.6 percent in the base year to 29.9 in 2030 – foreign borrowing is adjusted accordingly.

At the macro level, MAMS – like any other CGE model – requires the specification of the equilibrating mechanism (“closures”) for three macroeconomic balances: government, savings-investment, and the balance of payments. For the base scenario the following closures are used: (a) Government: the government accounts are balanced via adjustments in foreign borrowing; (b) Savings-investment: household savings adjust to generate exogenous GDP shares for domestically financed private investment; among other investment categories, FDI is determined by exogenous inflows, while government investment is financed within the government budget; and (c) Balance of payments: the real exchange rate equilibrates the balance by influencing export and import quantities and values (in foreign currency); the non-trade-related payments of the balance of payments (transfers and foreign investment) are non-clearing, kept fixed as shares of GDP. In the non-base scenarios, the treatment of the

¹¹ The exogenous part of total factor productivity growth is adjusted to generate such a growth path. In non-base scenarios, GDP growth is endogenous.

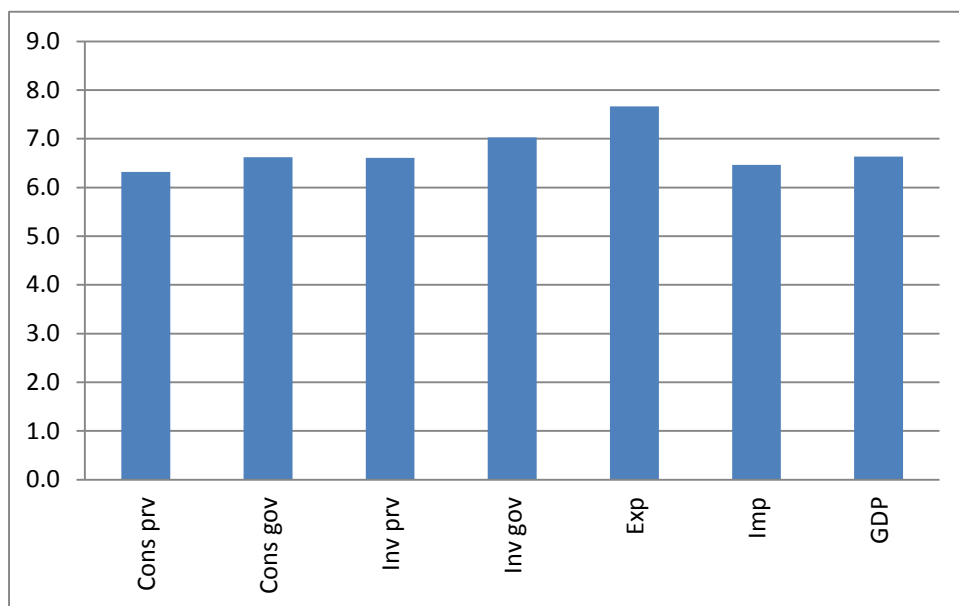
government balance varies as part of the design of the simulations; private investment becomes the clearing variable in the savings-investment balance, adjusting to make use of available financing; and the balance of payments rule remains the same as for the base.

For each simulation, MAMS provides the evolution over time for a wide range of data including: (a) macro indicators: GDP (split into private and government consumption and investment; exports; imports); the composition of the government budget, the balance of payments, and the savings-investment balance; total factor productivity; domestic and foreign debt stocks; (b) sectoral structure of production, incomes, exports, and imports; (c) poverty; and (d) labor market: wages, unemployment, and sectoral employment. Drawing on inputs from the PS analysis, these reports are expanded to include the evolution of *EXPY*, *HI*, *RCA*, *density*, and *OF*. The presented information is relevant for policymakers as they consider the attractiveness, potential pitfalls, and likely tradeoffs for alternative strategies for structural transformation, all of which take the current structure of our archetype SSA country's economy as their starting point.

Figure 4.1 shows key macroeconomic results for the base. In the base scenario, the economy evolves according to recent trends, with most macro aggregates growing at 6-7 percent per year, at the upper end of this range for exports and public investment. Per-capita household consumption grows at a rate of 3.2 percent per year. The exchange rate depreciates slightly over time. GDP growth is accompanied by a relatively rapid expansion of employment. The unemployment (+underemployment) rate is reduced from 24.4 percent in 2010 to 15.8 percent in 2030. Real wage grows 2.3 percent per year on average.

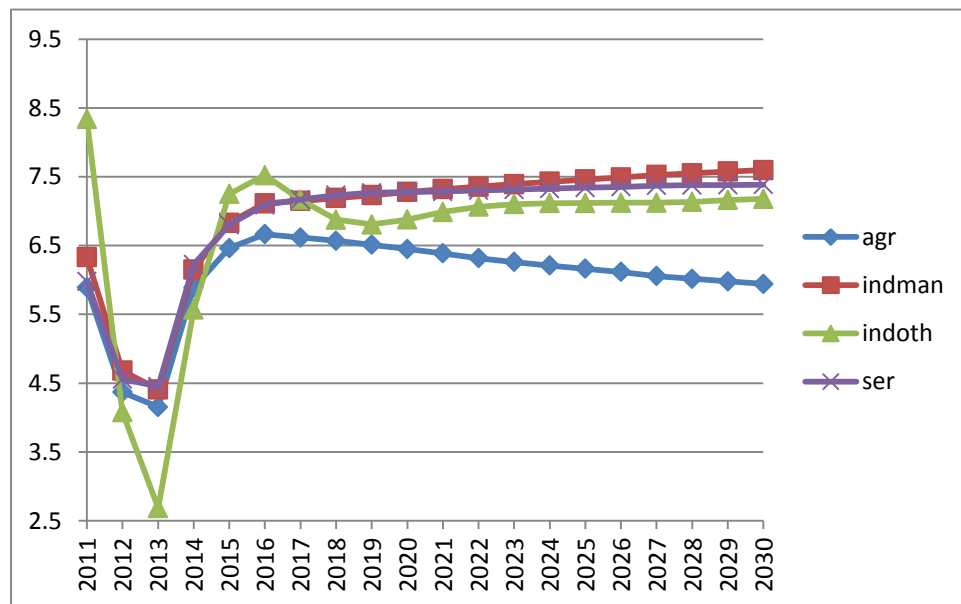
In terms of sectoral structure, growth for agriculture is constrained by the land supply, which is assumed to grow by 1 percent annually. Thus, the sectoral structure of VA and exports changes in favor of manufactures and services, with a positive effect on *EXPY* starting in the year 2017 (see Figure 4.1). To some extent, growth in the services sector is driven by the investment projects of the government, especially for the construction sector.

Figure 4.1: Real macro indicators by simulation (percent annual growth from first to final report year)



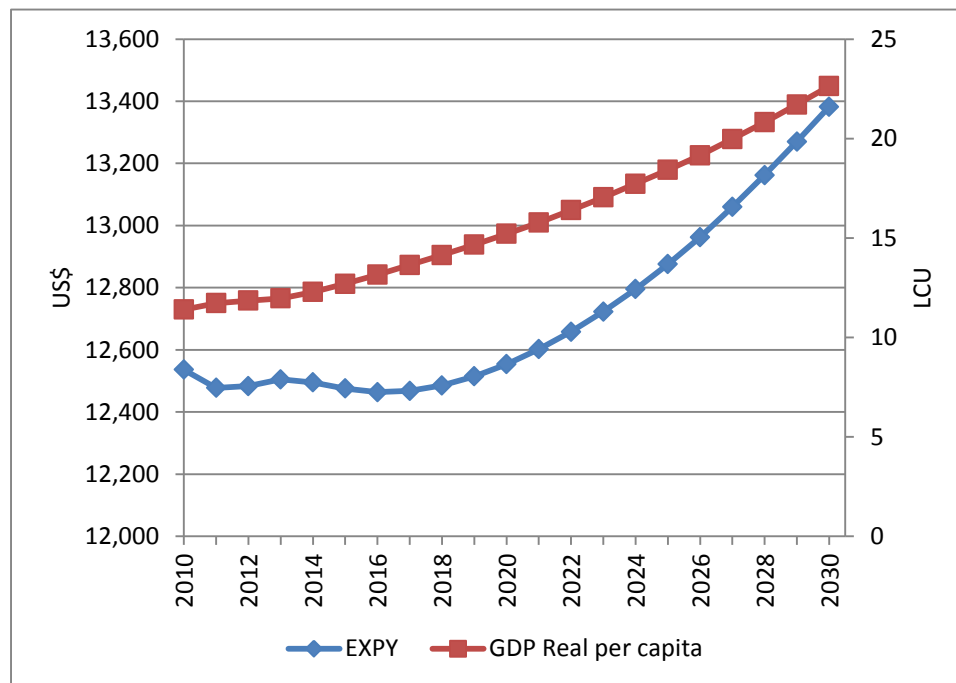
Source: Core-MAMS-PS simulations for archetype SSA country.

Figure 4.2: Real sectoral GDP growth rates in base scenario (percent)



Source: Core-MAMS-PS simulations for archetype SSA country.

Figure 4.2: EXPY and GDP per capita in base scenario (US\$ and LCU)



Source: Core-MAMS-PS simulations for archetype SSA country.

Non-base scenarios

In what follows we show selected results from the scenarios previously presented. Generally speaking, we focus on changes in the sectoral structure of our archetype SSA country in the year 2030, the last year of our simulation period.

In the sub-food scenario, which provides the basis for imposing increases in income tax rates in the other non-base scenarios, direct tax collection is (on average) 2.6, 1.3 and 0.2 percentage points higher than the base during 2015-2019, 2020-2025 and 2026-2030, respectively. Finally, in 2026-2030. In the infrastructure scenarios, we increase the investment in infrastructure that is targeted to specific sectors; the targeting is achieved by selecting non-zero TFP elasticities with respect to “other infrastructure” stock for selected sectors, and zero for the other sectors.

In addition, the said TFP elasticities are adjusted in order to match the marginal product of government capital used for model calibration (see Lofgren and Cicowiez (2014) for details on the procedure).

Macro Results

Generally speaking, at the macro level, and for the whole simulation period, the non-base scenarios that subsidize the targeted sectors do not show significant deviations relative to the base scenario. In fact, this is explained by the relatively small shock; in the sub-food and sub-chem scenarios we are subsidizing with 12.5 and 36.2 percent activities that represents 7.1 and 1.1 percent of GDP at factor cost, respectively. However, we do find some impact on the real exchange rate; particularly, in scenarios sub-chem and inf-chem, there is a real exchange rate appreciation that – as we will see – can hurt non-targeted tradable sectors.

Initially, in the infrastructure scenarios, there is an increase in GDP at factor cost, due to the increase in (total) final demand (i.e., public investment more than compensates for the decrease in private consumption and investment). In fact, we see a decline in labor unemployment combined with higher factor productivity in selected sectors. In fact, the positive impact of increasing investment infrastructure is present even without PS extensions to MAMS -- see additional simulation results in Appendix D. However, the positive impact of infrastructure is larger when PS extensions to MAMS are included in the simulations, particularly the assumption of endogenous world export prices.

Sectoral Results

In terms of broad sectoral categories (i.e., agriculture, mining, manufacturing, and services), none of the non-base scenarios that target the food sector shows significant changes relative to the base, an outcome related to the input-output relation between food and agriculture. Thus, one contribution from CGE analysis that is missing in stand-alone PS analysis is consideration of

the impact of export-oriented strategies on intermediate input requirements, both tradable and non-tradable. On the other hand, when the targeted sector is Chemical products, we found that the agricultural share in total value added decreases up to 2.1 percentage points relative to the base in 2030 (see scenario inf-chem), and 2.6 percentage points in the simulation that targets all manufacturing sectors using sector-specific infrastructure as the policy instrument. In addition, by comparing simulations with alternative labor proximities scaling, we see that manufacturing sectors are relatively close to each other and more distant from other sectors. As a result, subsidies to one sector brings in labor from other manufacturing sectors but less so from services or agriculture.

In all scenarios, the results show significant reallocation of resources within the manufacturing sector. For example, in scenario sub-chem, the share of Chemical products in total manufacturing value added increases from 3.4 (3.6) to 11.3 (9.5) in the year 2022 (2030).

The proximity-based labor reallocation works as intended. In qualitative terms, results are similar when comparing the same simulations with and without considering proximities to move labor across sectors. By assumption, when proximities are taken into account, the sectoral structure of the economy adjusts to a lesser extent during a given period, or more slowly; i.e., labor sectoral reallocation is smoother or slower.

As expected, in terms of sectoral employment, there is an increase in the share of the targeted sectors employment in the subsidy scenarios. On the other hand, when the processed food industry is promoted through infrastructure investment – i.e., with sectoral TFP increase as the driver of the sectoral growth --, we see a decrease in sectoral employment in the food sector, both as growth rate and as a share of total manufacturing employment. In scenarios without endogenous world export prices (see inf-food-nopweend and inf-food-nops in Appendix D), the decrease in sectoral employment in the food industry is even higher. In scenarios that target Chemical products, sectoral employment always increases.

In the long run, the increase in the world export price is highly relevant in order to obtain a lasting effect of the subsidy in terms of sectoral structure of production/employment. For example, an increase in the employment share of Chemical products within manufacturing. In addition, the scenario that combines endogenous world export prices with capability accumulation shows the larger increase in the share of promoted sectors in total employment. Of course, a decrease in the depreciation rate for accumulated (sectoral) capabilities also contributes to lengthen the impact of the subsidy and infrastructure scenarios.

In the subsidy scenarios where the capability accumulation effect is introduced alone (see Appendix D), we do not see a long-term impact in terms of the change in Chemical products (real) value added. In fact, given our assumptions, once the subsidy is eliminated, the TFP difference relative to the base scenario starts to decline. In contrast, when capability accumulation is combined with endogenous world export prices, the change in the sectoral structure of (real) value added is more significant and long-lasting. In other words, we find that synergies are at work; i.e., the sum of changes in various indicators are larger when the “positive” non-labor PS features (i.e., capability accumulation and endogenous world export prices) strengthened simultaneously than if one strengthens them one at a time and sums the two changes.

Trivially, investment in infrastructure has a more direct lasting effect than subsidizing the targeted sector (see scenarios sub-chem-nops and inf-chem-nops). Of course, this is explained by the fact that higher investment in 2015-2025 generates a larger capital stock with respect to base beyond 2025.

In terms of sectors, it is interesting to highlight the impact of considering cross capability accumulation effects. Again, at the broad sectoral level we do not find a large difference between the own and cross capability accumulation effects (see Appendix D). In general, two are the factors that contribute to explain this result: (a) based on scaled proximities, sectors are

not all that close, and (b) expansion in one sector doesn't change VA in other sectors by all that much.

Generally speaking, for some of the non-targeted sectors we see that the increase in wages and the appreciation of the exchange rate outweigh the gain that is obtained through the (cross) capability accumulation effects.

[TBC]

4. Conclusions

This paper analyzes the impact of alternative policies aimed at promoting the process of structural transformation in an archetype SSA country, using a novel approach based on the integration of elements of PS analysis into a CGE model, MAMS. In the analysis, learning by doing in production and exports may lead to improvements in TFP and higher world export prices. The distance between different sectors in product space influences the ease of labor reallocation and spread of TFP gains across sectors. Simulations address the impact of subsidies and infrastructure investment targeting different sectors, classified on the basis of their attractiveness according to PS criteria and the scope for improved export prices. Our simulation results show that the (long-term) impact of the said policies depends on the context: the effects tend to be more positive for more attractive sectors. While considerable progress has been made in terms of database development, additional research is needed to fine-tune the approach (inter alia considering additional contextual factors that influence the effects of sectoral targeting) and address remaining data issues, at least in part drawing on evolving approaches to model validation.

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Appendix A: Key concepts in product-space analysis

PS analysis offers a data-driven evaluation of the feasibility and desirability of alternative sectoral transformation options for a country, considering its initial structure and the global record. Drawing on data for exports and, in our application, VA, it generates both standard trade indicators and a set of new indicators that are related to the *proximity* between different commodities, the income levels that are associated with the countries that export individual commodities, and the export basket of individual countries. In this section, we will review these concepts, including the extensions and adjustments that we introduce for the purposes of this study.

PS analysis was pioneered in Hausmann, Hwang, and Rodrik (2007), Hausmann and Klinger (2006), and Hidalgo et al. (2007). This analysis is based on a country's current capabilities (or initial conditions) and on international evidence that arises from patterns of comparative advantage and path dependence in the basket of goods exports of a country, implicitly underpinned by similar path dependence in the production basket of the country. PS analysis provides information about the income and diversification potential of different sector strategies, considering links between sectors. The key data source for the PS analysis at its typical, most disaggregated level, is Comtrade's global trade records (the SITC Rev. 2 Classification at the 4-digit level, covering 784 goods and 130 countries from 1980 to 2010); this information is complemented by country-level data on GDP per capita.¹²

¹² The disaggregation of PS analysis is determined by the dataset that is used. For even more finely disaggregated analysis, the Comtrade HS database may be used.

One significant shortcoming of PS analysis is that it has typically been limited to the products (goods) covered by Comtrade, viewing these in isolation from other products.¹³ Moreover, for products that are non-traded, export data cannot be used to assess the capability of a country. Furthermore, *RCA* indicators are influenced by policy-induced distortions – although, given the large number of countries involved, the resulting distortion of *proximity*-based indicators (which appear in all core PS concepts) may be quite limited – and they are not ideal proxies for capability (a concept that is distinct from comparative advantage).

Since its inception, PS analysis has been applied to a wide range of countries, including numerous studies by the World Bank that have enriched its dialogue with clients. (See the reference section for a selection of studies.)

Empirically, PS analysis involves the construction of set of export-related indicators, showing both the historical record of a country and indicative projections into the future. Some of these – including the Herfindahl index (HI), and revealed comparative advantage (*RCA*) are standard.¹⁴ Other indicators, derived from network theory and validated empirically, have more recently been pioneered in the context of PS analysis (Hausmann and Klinger 2006; Hidalgo and Hausmann 2009; Hidalgo et al. 2007).

More specifically, the standard indicators that are relevant in the current model may be defined as follows, with the indices r (or r'), c (or c' or c''), and t referring to countries (“regions”),

¹³ In a recent pioneering analysis, Mishra, Lundstrom, and Anand (2011) address the role of service export sophistication in economic growth using the tools of PS analysis.

¹⁴ Indicators of the technological content of exports are also frequently included in analyses of structural transformation as it is indicative of the sophistication of a country in a given commodity category. Technologically sophisticated commodities tend to be associated with a high *PRODY*. For example, Lall (2000) classifies commodities into primary, resource-based, low-, medium- or high-tech; see also Lall, Weiss, and Zhang (2006).

commodities (often referred to as products, typically limited to goods), and years, respectively.¹⁵

- *HI* is a time- and country-specific measure of export concentration by country, and time period:

$$HI_{r,t} = \sum_c \left(\frac{E_{r,c,t}}{\sum_{c'} E_{r,c',t}} \right)^2$$

where $E_{r,c,t}$ is the value of exports for country r of commodity c in time t .

- *RCA* shows the degree of comparative advantage by country, commodity, and time. A country has an *RCA* in a commodity c if the following indicator has a value above unity:

$$RCA_{r,c,t} = \frac{\frac{E_{r,c,t}}{\sum_{c'} E_{r,c',t}}}{\frac{\sum_{r'} E_{r',c,t}}{\sum_{r'} \sum_{c'} E_{r',c',t}}} = \frac{\left[\begin{array}{c} \text{shr of commodity} \\ \text{in country exports} \end{array} \right]}{\left[\begin{array}{c} \text{shr of commodity} \\ \text{in world exports} \end{array} \right]} = \frac{\frac{E_{r,c,t}}{\sum_{r'} E_{r',c,t}}}{\frac{\sum_{i'} E_{r',c',t}}{\sum_{r'} \sum_{c'} E_{r',c',t}}} = \frac{\left[\begin{array}{c} \text{shr of country in} \\ \text{exports of commodity} \end{array} \right]}{\left[\begin{array}{c} \text{shr of country in} \\ \text{world exports} \end{array} \right]}$$

In the following, *RCA* refers to the above definition, i.e. a continuous variable with a lower limit of zero. The corresponding binary 0-1 variable is referred to as *RCA01* ($RCA01_{r,c,t} = 0$ if $RCA_{r,c,t} <$

¹⁵ In PS analysis, the indices c and i are typically used for country and product; in MAMS and many other CGE models, c is used for commodities (goods or services). In order to avoid confusion and to keep notation consistent throughout this study, we switch to r for countries (or “regions”; this follows the example of GTAP) and use c for commodities. It should also be noted that MAMS makes a distinction between commodities c (outputs) and activities a (producing outputs); in this application, there is a one-to-one mapping between the two. Whether the MAMS code refers to a or c depends on context.

1; $RCA01_{r,c,t} = 1$ if $RCA_{r,c,t} \geq 1$). [zz. A second continuous variant, $RCA01cnt$, is used in MAMS: $RCA01cnt_{r,c,t} = RCA_{r,c,t}$ if $RCA_{r,c,t} \leq 1$; $RCA01cnt_{r,c,t} = 1$ if $RCA_{r,c,t} > 1$). zz] On the basis of the evolution of their RCA s, exported goods may be classified as classic, emerging, disappearing, or marginal. The classics may be understood as the traditional exports of a country, i.e. commodities in which the country always has had a comparative advantage. The emerging champions are commodities in which the country did not have a comparative advantage in the past but developed it in recent years. The time periods 'past' and 'present' can be specified by the analyst. The disappearing commodities are those in which the country had a comparative advantage in the past but does not have it anymore, and the marginal commodities are those in which the country never has had a comparative advantage.

Indicators that more recently have been pioneered by PS analysis include:

- $PRODY_{c,t}$ indicates the potential income level of a commodity c in t . It is defined on the basis of GDP per capita ($GDPPC$) of all exporting countries, with the weight of each country defined by how important c is in its exports (measure by the share of c in the total export value of country r):¹⁶

¹⁶ The *PRODY* concept was developed by Hausmann, Hwang and Rodrik (2007). According to Schott (2008), *PRODY* may overestimate the income potential of complex manufactured commodities such as hi tech electronics if they are exported both by relatively poor countries like China and rich Western countries. However, Schott (2008) has also noted that for simpler commodities exported by most developing countries, especially low income ones, the *PRODY* is a reasonable representation of the income potential of the commodities exported.

$$PRODY_{c,t} = \sum_r \left[\frac{\left(\frac{E_{r,c,t}}{\sum_{c'} E_{r,c',t}} \right)}{\sum_{r'} \left(\frac{E_{r',c,t}}{\sum_{c'} E_{r',c',t}} \right)} \cdot GDPPC_{r,t} \right]$$

Some evidence suggests that developing countries that start to produce and export a commodity over time may be able to raise the prices that they receive as quality improves, reducing the price gap vis-à-vis developed country exporters of the same commodity (Hausmann, Hwang, and Rodrik 2007, pp. 13-14).

- *EXPY* shows the potential income level of the export basket of a country. It is defined using *PRODY* with each commodity *c* weighted by its share in the exports the country:

$$EXPY_{r,t} = \sum_c \frac{E_{r,c,t}}{\sum_{c'} E_{r,c',t}} \cdot PRODY_{c,t}$$

Econometric cross-country time-series indicates that *EXPY* is a strong and robust predictor of subsequent economic growth (Hausmann, Hwang, and Rodrik 2007, p. 3).

- The *proximity* between two commodities, *c* and *c'*, in time *t*, $\varphi_{c,c',t}$ ($0 \leq \varphi_{c,c',t} \leq 1$) is the key building-block for all network indicators in the PS analysis. It is derived from data on probabilities of having $RCA \geq 1$ ($rca01 = 1$) simultaneously for *c* and *c'*:

$$\varphi_{c,c',t} = \min \left\{ P(rca01_{c,t} | rca01_{c',t}), P(rca01_{c',t} | rca01_{c,t}) \right\}$$

where *P* (the conditional probability) is computed using all countries *r* in year *t*, and where

$$rca01_{r,c,t} = \begin{cases} 1 & \text{if } RCA_{r,c,t} > 1 \\ 0 & \text{if } RCA_{r,c,t} \leq 1 \end{cases}$$

- The *density* of a commodity c in which a country does *not* have an RCA , scaled to vary from 0 to 1, can be seen as a measure of the probability (or capability) of developing an $RCA \geq 1$ in commodity c in the future. For each commodity, it is the ratio between (a) the sum of all proximities between that particular commodity and all commodities in which the country has an $RCA \geq 1$; and (b) the sum of all proximities of the commodity (irrespective of whether or not the country has an RCA in the other commodity):

$$density_{r,c,t|rca01_{r,c,t}=0} = \frac{\sum_{c'|c \neq c'} \varphi_{c,c',t} \cdot rca01_{r,c',t}}{\sum_{c'|c \neq c'} \varphi_{c,c',t}}$$

- Open forest (OF) may be seen as the option value of a country's unexploited export opportunities. It is defined on the basis of proximities to and potential incomes of all the commodities in which the country could potentially develop an RCA . Mathematically, it may be expressed as follows:

$$OF_{r,t} = \sum_c \left\{ \sum_{c'} \left[\frac{\varphi_{c,c',t}}{\sum_{c''} \varphi_{c'',c',t}} (1 - rca01_{r,c',t}) \cdot rca01_{r,c,t} \cdot PRODY_{c',t} \right] \right\}$$

$$= \sum_{c|rca01_{r,c,t}=1} \left\{ \sum_{c'|rca01_{r,c',t}=0} PRODY_{c',t} \left[\frac{\varphi_{c,c',t}}{\sum_{c''} \varphi_{c'',c',t}} \right] \right\}$$

The second formulation of the definition states that, for an individual commodity c in which a country has an $RCA > 1$ ($RCA01 = 1$), OF may be defined as the potential income of every other commodity c' for which $RCA < 1$ ($RCA01 = 0$), weighted by the share of c' in the total proximities of c .

In addition, in MAMS, a proximity-weighted learning by doing process influences TFP by activity. The PS indicators in MAMS follow the disaggregation of the MAMS database and cover both Comtrade and non-Comtrade commodities. For the former, the Comtrade database is used; for the latter, we use 2007 data in the GTAP 8 database. The non-Comtrade commodities consist of services and a small subset of goods (including utilities and construction). Globally and for our archetype SSA country, the shares of exports in total output for these commodities are very small compared to the shares for Comtrade commodities. Given this, we used GTAP VA data for the non-Comtrade PS indicators. Technically, it is straightforward to define *RCA* and *proximity* indicators using export data for one commodity subset and VA data for another commodity subset. The economic interpretation is that, for relatively *non-tradable* commodities (covered by GTAP data), the degree of comparative (or competitive) advantage for country is measured by how important a commodity is in the VA of a country compared to their importance in global VA. At the same time, for relatively tradable commodities (covered by Comtrade), the degree of comparative advantage for country is measured in a standard manner by the how important a commodity is in the exports of a country compared to their importance in global exports. In effect, this formulation makes it possible to consider in an integrated manner the existing patterns in terms of the development of capabilities in service sectors in parallel with goods sectors.^{17 18}

¹⁷ Note that the purpose is to assess the capability of a country to become an efficient producer in a given sector, either for exports or, when trade is less important, as a supplier of inputs or labor to sectors that are close in product space. In such an assessment, it is clearly not possible to use export data for sector without exports. However, for sectors with exports accounting for only a minor part of output (for example construction), it would not be meaningful to assess capability with reference to exports, hence the preference for using VA data.

¹⁸ To add a further consideration, for some export-focused indicators, like *HI*, export data (globally very limited) will be used also for GTAP commodities.

Among the above indicators, *proximity* is most important to MAMS and its database as it influences both labor reallocation and learning by doing. Drawing on *PRODY* and additional econometric analysis, MAMS also incorporates insights about the likely evolution of export prices as a country expands exports for goods associated with countries at a higher level of GDP per capita. MAMS reports of simulation results cover a wider range of indicators: *EXPY*, *HI*, *RCA*, *RCA01*, *RCA01CNT*, *DENSITY*, and *DENSITYCNT*, and *OF*).

Appendix B: Producer profit maximization in a product-space setting

This appendix analyzes the profit-maximization problem of the producer of an activity a in a setting where product space *proximity* influences the profitability of the reallocation of factors between activities (sectors). A simplified version such a profit-maximization may be stated as follows:¹⁹

$$\text{maximize } p_a \cdot Q_a - \sum_f \sum_{a'} w_{f,a'} \cdot QFR_{f,a',a}$$

subject to

$$Q_a = \alpha_a \left[\sum_f \delta_{f,a} \cdot fp_{f,a}^{-\rho} \cdot QF_{f,a}^{-\rho} \right]^{-1/\rho} ; QF_{f,a} = \sum_{a'} \phi_{f,a',a}^{scal} \cdot QFR_{f,a',a} ; \text{ and } QFR_{f,a',a} \geq 0$$

where p_a = output price; Q_a = output quantity; $w_{f,a'}$ = market wage per physical unit of factor f linked to in source activity a' ; $QFR_{f,a',a}$ = the physical quantity of f reallocated from source activity a' to the current activity a . α_a , $\delta_{f,a}$, ρ , and $fp_{f,a}$ = CES function parameters for efficiency, factor shares, exponent, and factor-specific productivity, respectively; $QF_{f,a}$ = effective employed quantity of factor f in activity a ; $\phi_{f,a',a}^{scal}$ = scaled *proximity* between any source activity a' and the current destination activity a with respect to factor f ($0 < \phi_{f,a',a}^{scal} \leq 1$, with a value of 1 for the special case where $a = a'$ also covered by QFR , i.e. “reallocation of a factor to its original

¹⁹ To simplify, this mathematical statement suppresses intermediate input use, domain controls, the time index, and the activity subscript for the exponent ρ .

activity with identical physical and effective factor quantities).²⁰ For factors without this factor reallocation mechanism, the *proximity* parameter is 1 for all relevant a - a' mappings.

The Lagrangian, L , for this problem may be stated as follows:

$$L = p_a \cdot Q_a - \sum_f \sum_{a'} w_{f,a'} \cdot QFR_{f,a',a} + V_a \left[\alpha_a \left[\sum_f \delta_{f,a} \cdot \bar{p}_{f,a}^{-\rho} \cdot QF_{f,a}^{-\rho} \right]^{-1/\rho} - Q_a \right] \\ + \sum_f r_{f,a} \left[\sum_{a'} \phi_{f,a',a}^{scal} \cdot QFR_{f,a',a} - QF_{f,a} \right]$$

where V_a = the shadow price of output; $r_{f,a}$ = the efficiency-unit shadow rent of factor f in activity a . The first-order conditions may be rendered as:

²⁰ As noted in footnote of Appendix A, in the MAMS database, there is a one-to-one mapping between commodities, c , and activities, a . Given this, PS indicators may refer to either, depending on what is most convenient in any specific context. Since Appendix B refers to activities and not to their outputs, we here use a .

1. $\frac{\partial L}{\partial Q_a} = p_a - V_a = 0$
2. $\frac{\partial L}{\partial QF_{f,a}} = (-1/\rho)V_a \cdot \alpha_a \left[\sum_{f'} \delta_{f',a} \cdot fp_{f',a}^{-\rho} \cdot QF_{f',a}^{-\rho} \right]^{-1/\rho-1} \left[(-\rho) \cdot \delta_{f,a} \cdot fp_{f,a}^{-\rho} \cdot QF_{f,a}^{-\rho-1} \right] - r_{f,a} = 0$
3. $\frac{\partial L}{\partial QFR_{f,a',a}} = -w_{f,a'} + r_{f,a} \cdot \varphi_{f,a',a}^{scal} \leq 0;$
4. $QFR_{f,a',a} \geq 0;$
5. $QFR_{f,a',a} (-w_{f,a'} + r_{f,a} \cdot \varphi_{f,a',a}^{scal}) = 0$
6. $\frac{\partial L}{\partial V_a} = \alpha_a \left[\sum_f \delta_{f,a} \cdot fp_{f,a}^{-\rho} \cdot QF_{f,a}^{-\rho} \right]^{-1/\rho} - Q_a = 0$
7. $\frac{\partial L}{\partial r_{f,a}} = \sum_{a'} \varphi_{f,a',a}^{scal} \cdot QFR_{f,a',a} - QF_{f,a} = 0$

Using 1 to substitute for V in 2, noting that $(-1/\rho) \cdot (-\rho) = 1$, and rearranging the remaining equations permits us to summarize the first-order conditions for producer profit maximization as follows (with the above equation numbers in paranthesis):

- 8 (1-2). $p_a \cdot \alpha_a \left[\sum_{f'} \delta_{f',a} \cdot fp_{f',a}^{-\rho} \cdot QF_{f',a}^{-\rho} \right]^{-1/\rho-1} \left[\delta_{f,a} \cdot fp_{f,a}^{-\rho} \cdot QF_{f,a}^{-\rho-1} \right] = r_{f,a}$
- 9 (3). $w_{f,a'} \geq r_{f,a} \cdot \varphi_{f,a',a}^{scal}$
- 10 (4). $QFR_{f,a',a} \geq 0$
- 11 (5). $QFR_{f,a',a} (r_{f,a} \cdot \varphi_{f,a',a}^{scal} - w_{f,a'}) = 0$
- 12 (6). $Q_a = \alpha_a \left[\sum_f \delta_{f,a} \cdot fp_{f,a}^{-\rho} \cdot QF_{f,a}^{-\rho} \right]^{-1/\rho}$
- 13 (7). $QF_{f,a} = \sum_{a'} \varphi_{f,a',a}^{scal} \cdot QFR_{f,a',a}$

The last set of equations may be interpreted as follows:

8. The marginal value product of factor f in a (RHS) equals the shadow wage of f in a (LHS); both RHS and LHS are expressed in efficiency units.

9. The market wage of f in a' is larger than or equal to the shadow rent of f in a' scaled by the relevant *proximity* indicator.
10. The physical quantity of f reallocated from any activity a' to a is non-negative.
11. If a positive quantity of f is reallocated from a' to a , then the market wage of f in source activity a' has to be equal to the shadow rent of f in destination activity a scaled by the *proximity* indicator. (If the source wage were larger/smaller, then a marginal decrease/increase in the reallocated quantity would raise profits.) In effect, this means that, the lower the scaled *proximity*, the higher the effective-unit destination sector shadow wage that is required for reallocation to take place.
12. Output level for activity a is a function of effective-unit factor quantities.
13. Available quantity of f in a in efficiency units is the sum of quantities in physical units received from different activities a' multiplied by scaled proximity.