Analyzing Economic Structural Change in a General Equilibrium Framework: The case of Switzerland from 1990 to 2001

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May 1, 2005†

Abstract

Structural change is influenced by many factors, including technological changes and shifts in consumer preferences. These factors have an important impact on economic performance through the reallocation of resources from one economic activity to another. Applying SwissAGE, a general equilibrium model for Switzerland, this study focuses first on the estimation of changes in technology and consumer preferences. It shows then how economic history can be explained in terms of these driving factors. In particular, it shows that decrease in capital/labour ratio mitigates growth in real GDP and increase in export-oriented production heavily contributes to rapid growth in Swiss trade across the period 1990 to 2001.

JEL classification: D24; D58; C68; F14

Keywords: Technological change; Preference change; Dynamic CGE modelling; Swiss structural change; Trade growth

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†This paper has been prepared for presentation at the 8th Annual Conference on global Economic Analysis, Lübeck, Germany, June 9-11, 2005.

1 Introduction

Structural change is important to economic growth. Structural change is influenced by many factors, including technological changes and shifts in consumer preferences. These factors have an important impact on economic performance through the reallocation of resources from one economic activity to another. This study focuses first on the estimation of changes in technology and consumer preferences. It shows then how economic history can be explained in terms of these driving factors. In particular, it shows that decrease in capital/labour ratio mitigates growth in real GDP and increase in export-oriented production heavily contributes to rapid growth in Swiss trade across the period 1990 to 2001.

The difficulty in the estimation is that household preferences and industry technologies are naturally exogenous variables and are not observable. This difficulty is overcome by first conducting an historical simulation. In this simulation, variables that can be observed across the period 2001 to 1990 are exogenous and shock with their actual movements[1]. On the other hand, naturally exogenous but unobservable variables are made endogenous. The estimation of their movements across the period is realized by applying SwissAGE, a general equilibrium model for Switzerland. Once the historical simulation has been completed, a decomposition simulation can be conducted. In this simulation, estimates of unobservable exogenous variables are used to explain structural change in the economy across the period in consideration.

The implementation of historical and decomposition simulations has been first developed by Dixon and Rimmer (2002). Their initial motivation for the historical simulation was to update input-output tables from 1987 to 1994. As the historical simulation produces also estimates of changes in tastes and technology, they analyzed the Australian motor vehicle industry for the same period. They found, for example, that preferences of users of cars strongly shift towards the imported product or that industry's technology moved largely towards the use of capital with respect to. Using these results, they were able then to decompose the performance of the motor vehicle industry over the period 1987 to 1994 into the parts attributable to movements in changes in tariffs relative to changes in other variables (e.g. tastes and technology). They found out, for example, that the output for motor vehicles increase substantially despite the negative impact of the lower tariffs and the approximatively zero productivity growth in factor inputs during this period. The decomposition simulation showed that the reason of the large increase in output came from the strong shift in industry technologies favoring the use of motor vehicles.

The use of historical and decomposition simulation has been applied recently to the US economy from 1992 to 1998 (Dixon and Rimmer, 2003; Dixon and Rimmer, 2004). The decomposition results show that technological changes reducing costs in export-oriented industries or increasing inputs of commodities that are heavily imported are the main determinant of the rapid growth in

[1] We choose our base year to be 2001 in order to use the new sectoral classification for Switzerland. However all results are given on the 1990 year basis.

international trade.

The purpose of this paper is to show how the estimation of changes in technology and consumer preferences can be implemented in a general equilibrium model for Switzerland. SwissAGE is a dynamic, computable general equilibrium model of Switzerland[2]. It is based on a miniature version (Dixon and Parmenter, 1996) of the Monash model developed by Dixon and Rimmer (2002). The structure of the model is presented in the following section. The historical and decomposition closures are explained in section 3. Section 4 presents the historical simulations across the period 1990 to 2001 and a sketch model for helping with the interpretation of the results. In section 5 we analyze both the growth in GDP and in trade for Switzerland using the decomposition simulation across the period 1990 to 2001. Conclusion is given in the last section.

2 The Model

SwissAGE is a dynamic, computable general equilibrium model of Switzerland. Its theoretical structure is based on a miniature version (Dixon and Parmenter, 1996) of the Monash model developed by Dixon and Rimmer (2002). SwissAGE assumes a small open economy. It consists of industries and investors, households, foreigners and the national government. The model assumes constant return to scale in each activity. We require that marginal cost equals marginal revenue which makes pure profits impossible to earn for any activity. Market clearing conditions imply that supply equals demand for commodities. Finally, the model is assumed to be recursive dynamic with endogenous investment.

Producers are assumed to minimize their cost subject to a production technology represented by a two-stage production function. The nested structure of the input side is shown in figure 1[3]. The top level is a Leontief (LT) combination of intermediate inputs and value-added. Following Armington (1969), intermediate demand is represented as a composite of imported and domestic goods. Value-added is a combination of labour and capital using a constant elasticity of substitution (CES) function.

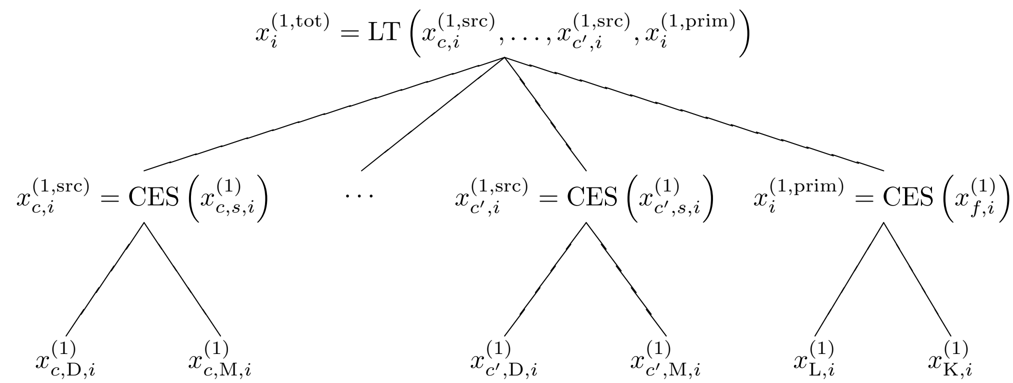
Producers are also assumed to maximize their revenue subject to transformation frontiers represented by a constant elasticity of transformation (CET) function[4]. Figure 2 reflects the structure of transformation. The upper level is a mixture of all the commodities produced by each industry. The lower level allows conversion of each commodity into goods destined for export or for local use and is governed by a CET transformation frontier. It follows from the

[2]SwissAGE uses the GEMPACK software developed at CoPS, Monash University, Australia (Harrison and Pearson, 1996).

[3]Most variables are defined in the appendix. The convention is as follows. Indexes c, f and i denote sets of commodities, factors (L=Labour and K=Capital) and industries respectively. Source of commodities (D=Domestic and M=Imports) and destination of goods (D=Domestic and E=Exports) are respectively denoted by indexes s and d. Superscripts in parentheses give the type of user (1=Industries, 2=Investors, 3=Households and 4=Foreigners) and add a short description to the variable when it is necessary (prim=Primary, src=Source, dst=Destination, tot=Total, mar=Margin, pur=Purchase, bas=Basic, imp=Imports, ind=Industry).

[4]In this study however all industries are assumed to produce a single commodity.

Figure 1: Structure of production



assumed input-output separability specification that the composition of inputs is independent the composition of outputs.

We assumed that investors behave in the same way as producers except to one difference. They do not use directly primary factors as inputs to capital formation.

Households are assumed to maximize a nested utility function subject to a budget constraint. As for producers and investors, the lower level allows for imperfect substitution, represented by a CES function, between domestic and imported commodities. At the upper decision level, consumer preferences for composite commodities are described by a Klein-Rubin function leading to the linear expenditure system (LES) as it is shown in figure 3.

Foreigners are assumed to purchase only commodities produced domestically. Their demand for exports exhibits infinite elasticity in prices expressed in foreign currency which reflects that Switzerland is a small open economy. This means that export prices are exogenously fixed by world prices.

Public consumption is realized through government demands for both imported and domestically produced goods and services. The commodity composition of government consumption is assumed to be exogenously determined,

Figure 2: Structure of transformation

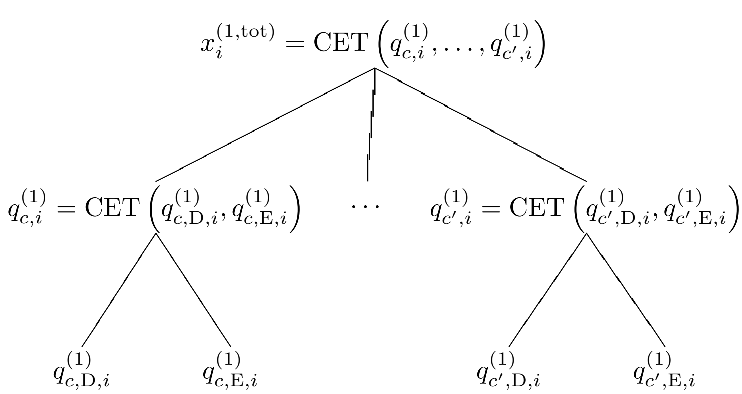
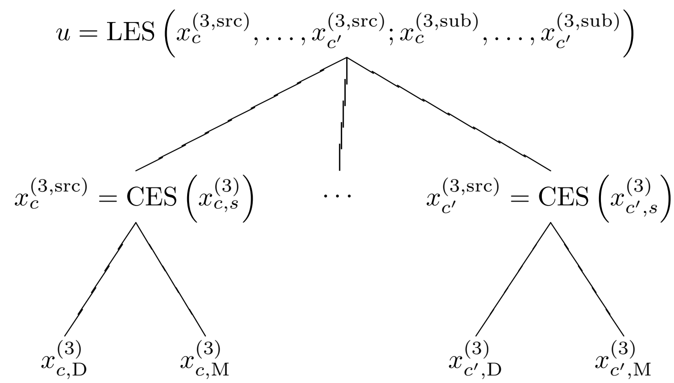


Figure 3: Structure of preferences



whereas the aggregate public consumption is assumed to move with aggregate private consumption.

Producers, investors and importers are assumed to earn zero pure profits. The price received by producers is equal to the unit costs of production and the price received by investors is equal to the unit costs of constructing capital. The basic prices of imports are defined as their c.i.f. duty-paid prices in domestic currency. Regarding purchasers' prices for each user, they are equal to the sums of basic prices and commodity taxes.

Market clearing conditions impose that supply equals demand. The supply for domestic commodities is the sum over producers of commodities and the demand is the sum over uses of commodities. We assume infinite elasticity of the supply of imports which means that the supply of imports can be interpreted as the percentage change in the total demand for imports. Regarding factor markets, the current supply of capital is equal to the demand in that period for any industry whereas the supply of labour is equal to the aggregate demand for labour over industries.

Capital stock available for use in each industry at the end of one period is determined by the current capital stock depreciated at a given rate plus and the current level of investment. Aggregate investment is endogenous to the model as well as the allocation of investment across industries which depends on rates of return. These are determined endogenously reflecting the interaction of demand for capital with exogenously given capital supplies.

Finally the model may allow for indexation of nominal wage rates to the consumer price index. The percentage change of the latter is defined as a weighted sum over the percentage change of the source-specific good prices.

3 Historical and Decomposition Closures

This section is entirely drawn from Dixon and Rimmer (2002) and Dixon and Rimmer (2003). It presents the underlying theory of the historical and decomposition closures. Details of implementing the historical closure from the decomposition closure in SwissAGE is given in the appendix.

For any year the representation of the model may be expressed in the following compact form:

$$F(X) = 0 \tag{1}$$

where F is a vector of m differentiable functions of n variables X, $n > m$. The variables X include prices and quantities applying for a given year and the m equations in 1 impose the usual conditions for applied general equilibrium models such as: demands equal supplies, demands and supplies reflect utility and profit maximizing behavior; prices equal unit costs; and end-of-year capital stocks equal depreciated opening capital stocks plus investment.

In using the model we always have available an initial solution, X^0, of equation 1 derived mainly from input-output data for a particular year. In simulations, we compute the movements in m variables (the endogenous variables) away from their values in the initial solution caused by movements in the remaining $n-m$ variables (the exogenous variables) away from their values in the initial solution. In most simulations the movements in the exogenous variables are from their values in one year to their values in the next year. Correspondingly, the results for the endogenous variables refer to movements from one year to the next. However, in the historical and decomposition simulations considered in this study, the movements in the exogenous variables refer to changes over several years rather than one year. Thus, in these simulations, the movements in the endogenous variables refer to changes over the entire considered period.

In order to be able to solve the model, we must close the model, that is we have to choose which of the $n - m$ variables have to be included in the exogenous set. In a decomposition closure we include in the exogenous set all naturally exogenous variables, i.e., variables not normally explained in a computable general equilibrium (CGE) model. These may be observable variables such as tax rates or unobservables such as technology and preference variables.

On the other hand, historical closures include in their exogenous set observable and assignable variables. Observables are those for which movements can be readily observed from statistical sources for the period of interest. Usually the observables include a wide array of macro and industry variables but not intermediate input flows of commodity to industry. Assignable variables are naturally exogenous and are therefore exogenous in decomposition closures as well as historical closures. The key feature of an assignable variable in an historical simulation is that its movement can be assigned a value (possibly not unique) without contradicting anything that we have observed about the historical period or wish to assume about that period. We clarify this concept later in this section in the discussion of equation 2.

With reference to the two closures we can partition the variables into four parts. Let

$$X^{HD},\ X^{H\bar{D}},\ X^{\bar{H}D},\ \text{and}\ X^{\bar{H}\bar{D}}$$

be the set of variables in the model, where H and $\bar{H}$ denote exogenous and endogenous in the historical closure, and D and $\bar{D}$ denote exogenous and endogenous in the decomposition closure, then

Table 1: Categories of variables in the historical and decomposition closures

	$X^{H\bar{D}}$	$X^{\bar{H}D}$
1	Public consumption by commodity	Commodity composition of public consumption
	Aggregate public consumption	Ratio of private to public consumption
2	Private consumption by commodity	Shifts in household preferences
	Average taste shift	Average propensity to consume out of GDP
3	Imports by commodities	Shifts in import vs domestic preferences
4	Aggregate investment	Uniform shift in investment/capital ratios
5	Exports by commodities	Shifts in export vs domestic transformation
6-7	Employment and capital inputs by industry	Primary-factor-saving technical change and capital/labour bias in technical change
8	Output by commodity	Commodity-using technical change in output
	X^{HD}	
	Population	
	C.i.f. import prices and f.o.b export prices in foreign currency	
	Policy variables, e.g. tax and tariff rates	
	$X^{\bar{H}\bar{D}}$	
	Demands for intermediate inputs	
	Demands for margin services	

- $X^{H\bar{D}}$ denotes the set of variables that are exogenous in the historical closure but endogenous in the decomposition closure,

- $X^{\bar{H}D}$ denotes the set of variables that are endogenous in the historical closure but exogenous in the decomposition closure,

- X^{HD} denotes the set of variables that are exogenous in both historical and decomposition closures, and

- $X^{\bar{H}\bar{D}}$ denotes the set of variables that are endogenous in both historical and decomposition closures.

Table 1 gives examples of the partitioning of variables used in this model. As indicated, variables in X^{HD} are population size, foreign currency prices of imports and policy variables such as tax rates and tariff rates. The values of these variables are readily observable (included in H) and are not normally explained in CGE models (included in D).

Examples of variables in $X^{\bar{H}\bar{D}}$ are demands for intermediate inputs and demands for margins services (e.g. road transport) to facilitate commodity flows from producers to users. In the absence of end-of-period input-output tables, movements in these variables are not readily observable or assignable (not included in H) and are normally explained in CGE models (not included in D).

Variables in $X^{H\bar{D}}$ include, at the industry or commodity level, outputs, employment, capital, investment, exports, imports, private consumption and numerous price deflators. Also included are numerous macro variables such as the exchange rate and the average wage rate. CGE models normally aim to explain the effects on these variables of policy changes, changes in technology and other changes in the economic environment. Hence these variables are naturally endogenous, i.e. they belong to the D set, and because changes in their values can be readily observed they belong to the H set.

$X^{\bar{H}D}$ contains the same number of variables as $X^{H\bar{D}}$ with each variable in $X^{H\bar{D}}$ having a corresponding variable in $X^{\bar{H}D}$. These corresponding variables are predominantly unobservable technological and preference variables. Such variables are not normally explained by CGE models and are therefore exogenous in the decomposition closure. However in the historical closure they are endogenous with the role of giving the model enough flexibility to explain the observed movements in the variables in $X^{H\bar{D}}$. Table 1 shows examples of corresponding pairs from $X^{\bar{H}D}$ and $X^{H\bar{D}}$. As indicated in the table, in our historical simulation we use shifts in household preferences to accommodate observations on consumption by commodity, twists in import-domestic preferences to accommodate observations on import volumes, etc.

The principles underlying the four-way partitioning of the variables in the historical and decomposition closures can be clarified by an example. Let total intermediate demand of commodity c, X_c, be represented by the following equation:

$$X_c = \sum_i B_{c,i} B_c Z_i \tag{2}$$

where
Z_i is the activity level (overall level of output) in industry i; and
$B_{c,i}B_c$ is the input of commodity c per unit of activity in industry i with $B_{c,i}$ and B_c being technological variables which can be used in simulating the effects of changes in the input of commodity c per unit of activity in industry i and the input of commodity c per unit of activity in all industries.

In decomposition mode, $B_{c,i}$ and B_c are exogenous and Z_i and X_c are endogenous. Suppose that movements in the activity levels, Z_i, are not observed but that we have observed the movements over an historical period in total intermediate demand, X_c (possibly from information on commodity outputs, imports and final usage). Suppose that we wish to assume uniform input-c-using technical change. Then in historical mode we can use movements in B_c to explain observed movements in X_c and we can assign a uniform value (possibly zero) to the percentage movements in $B_{c,i}$ for all industry i. In this example, Z_i is a member of $X^{\bar{H}\bar{D}}$ and the assignable variable $B_{c,i}$ is a member of X^{HD}. X_c is a member of $X^{H\bar{D}}$ and B_c is the corresponding member of $X^{\bar{H}D}$.

Having allocated the variables to the four categories, we can compute historical and decomposition solutions, starting with the historical solution of the form:

$$X^{\bar{H}} = G^H(X^H) \tag{3}$$

where X^H and $X^{\bar{H}}$ are the exogenous and endogenous variables in the historical closure, i.e. $X^H = X^{HD} \cup X^{H\bar{D}}$ and $X^{\bar{H}} = X^{\bar{H}D} \cup X^{\bar{H}\bar{D}}$, and G^H is an m-vector of differentiable functions. By observing and assigning X^H for two years, s and t, we can use equation 3 to estimate percentage changes over the interval [s,t], $x^{\bar{H}}$, in the variables in $X^{\bar{H}}$. Thus we combine a large amount of disaggregated information on the economy (the movements in the variables in X^{H}) with a CGE model to estimate movements in a wide variety of technological and preference variables, $X^{\bar{H}D}$, together with movements in more standard endogenous variables, $X^{\bar{H}\bar{D}}$.

Next we move to the decomposition closure which gives a solution of the form:

$$X^{\bar{D}} = G^{D}(X^{D}) \tag{4}$$

where X^{D} and $X^{\bar{D}}$ are the exogenous and endogenous variables in the decomposition closure, i.e. $X^{D} = X^{HD} \cup X^{\bar{H}D}$ and $X^{\bar{D}} = X^{H\bar{D}} \cup X^{\bar{H}\bar{D}}$, and G^{D} is an m-vector of differentiable functions. Following the method pioneered by Johansen (1960), we can express equation 4 in log-differential or percentage change form as

$$x^{\bar{D}} = B \cdot x^{D} \tag{5}$$

where $x^{\bar{D}}$ and x^{D} are vectors of percentage changes in the variables in $X^{\bar{D}}$ and X^{D}, and B is an m by $n-m$ matrix in which the ij-th element

$$B_{ij} = \frac{\partial G_i^{D}(X^{D})}{\partial X_j^{D}} \frac{X_j^{D}}{X_i^{\bar{D}}} \tag{6}$$

is the elasticity of the i-th component of $X^{\bar{D}}$ with respect to the j-th component of X^{D}.

With the completion of the historical simulation, the percentage changes in all variables are known. In particular the vector x^{D} is known. Thus we can use equation 5 to compute values for $x^{\bar{D}}$ over the period s to t.

The advantage of working with equation 5 rather than equation 4 is that the former can be used to give a decomposition of the percentage changes in the variables in $X^{\bar{D}}$ over the period s to t into the parts attributable to movements in the variables in X^{D}. This is a legitimate decomposition to the extent that the variables in X^{D} are genuinely exogenous, that is, can be thought of as varying independently of each other. In setting up the decomposition closure, the exogenous variables are chosen with exactly this property in mind. Thus, among variables in X^{D}, we find policy variables, technology variables, taste variables and international variables (e.g. foreign currency prices) all of which can be considered as independently determined and all of which can be thought of as making their own contributions to movements in endogenous variables such as incomes, consumption, exports, imports, outputs, employment and investment.

In this study, we use the historical closure, developed in the next section, in estimating changes in technology and tastes variables. Using then the decomposition closure, we can compute, via equation 5, the contribution of the movement in the j-th exogenous variable to the percentage movement in the i-th endogenous variable

$$\Theta_{ij} = B_{ij} \cdot x_j^{D} \tag{7}$$

as the product of B_{ij}, the elasticity of the i-th component of $X^{\bar{D}}$ with respect to the j-th component of X^{D}, with the percentage change in the j-th element of

x^D. Because equation 4 represents a non-linear system of equations, the effect on endogenous variable i over the period s to t of movements in exogenous variable j cannot be computed unambiguously. The effects of movements in an exogenous variable depend on the values of other exogenous variables. In terms of equation 7, the problem is to decide at which values of the exogenous variables to evaluate B_{ij}. The most natural choice is to use mid-point values to evaluate the elasticities defined in equation 6. In the decomposition analysis in this study, we use a procedure due to Harrison, Horridge, and Pearson (2000) which, in effect, evaluates B_{ij} as the average of the values generated as we move the exogenous variables in the decomposition simulation in small steps along a straight line from their values in year s to their values in year t.

4 Historical simulation

Historical simulations allow the estimation of technology and preference variables (components of $X^{\bar{H}D}$) once information on observable variables have been incorporated into the model (components of $X^{H\bar{D}}$). As explained in the previous section, this means moving from the decomposition closure to the historical closure or in other words endogenization of naturally exogenous variables and exogenization of naturally endogenous variables. As will become apparent, the historical closure is complicated and unusual. We are going to develop the historical closure in a series of 8 steps. In this process, the naturally endogenous variables for which we have data are cumulatively exogenized. The steps are designed in order to have a valid closure at the end of each step. We are thus able to perform an historical simulation at the end of each step. Comparison of results for successive simulations show the effects of the additional data introduced at each step. Results from this step-by-step approach applied for 1990 to 2001 are shown in table 3. At the end of all the steps, historical simulations give estimates of technology and preference variables which are reported in table 4.

For the sake of clarity, in developing the historical closure[5], we are going to use a sketch model of SwissAGE. It will be also useful for understanding the broad features of the results. No sectoral disaggregation is brought in the sketch model whereas the applied model is currently run with 14 industries. The sketch model is presented in table 2. There are 8 equations and 8 endogenous variables. $X^{H\bar{D}}$ denotes the set of variables that are exogenous in the historical closure but endogenous in the decomposition closure whereas $X^{\bar{H}D}$ denotes the set of variables that are endogenous in the historical closure but exogenous in the decomposition closure. At each step a naturally endogenous variable in the set $X^{H\bar{D}}$ is swapped with its corresponding naturally exogenous variable in the set $X^{\bar{H}D}$. Thus the naturally endogenous variable becomes exogenous and its corresponding naturally exogenous variable becomes endogenous.

Equations in table 2 are listed in the order of the steps we are going to go through. We label them according to their corresponding step number. Equation S-0 of the sketch model is the GDP identity in constant-price terms. The next equation defines the ratio $\psi^{\mathrm{C/G}}$ of private consumption C to public

[5]The development of the historical closure in SwissAGE is given in the appendix.

consumption G. Equation S-2 relates the sum of private consumption and public consumption to GDP via the average propensity to consume $\psi^{\mathrm{C/GDP}}$. The following equation relates imports M to GDP, the exchange rate ϕ and to an import/domestic preference variable Υ^{src}. Equation S-4 defines the ratio $\psi^{\mathrm{I/K}}$ of investment I to capital K. The next equation relates exports X to the exchange rate and to an export/domestic preference variable Υ^{dst}. Equation S-7 relates the capital/labour ratio to the exogenous rate of return ROR, a technology shift variable A, the exchange rate and to a capital/labour twist variable Υ^{prim}. This equation is derived assuming that the value of marginal product of capital equals the rental on capital, R,

$$P\frac{\partial f}{\partial K}1/A = R \tag{8}$$

or equivalently,

$$MPK = A\frac{R}{P_K}\frac{P_K}{P} = A \cdot ROR \cdot \frac{P_K}{P} \tag{9}$$

where P_K and P are the price indexes for capital goods and for domestic goods. The rate of return is viewed as the ratio of the rental price of capital to the asset price. Recognizing that the marginal product of capital, MPK, is a monotonically decreasing function of the capital/labour ratio, technology has a negative impact on this ratio. The ratio of the cost of units of capital to the domestic price index can be viewed as a measure of real devaluation of the Swiss franc, since the former includes import prices but not export prices whereas the latter includes export prices but not import prices. In equation 9, the real devaluation is interpreted as a decreasing function of the exchange rate which means that it has a positive impact on the capital/labour ratio. The last equation of the sketch model is the production function relating real GDP to primary factors, capital K and labour L, and to the technology shift term. Labour is assumed to be fixed.

Step 0 - Naturally exogenous variables

A preliminary step to the 8 steps is to shock all the variables that are exogenous in both the historical and decomposition closures (the set of variables X^{HD} listed in table 1) for which we have information on their actual movements across the period 1990 to 2001. These variables are population and tariff rates. In this step we introduce also information on the general price level. In terms of the sketch model this means that we have to exogenize the price index P and to endogenize the exchange rate ϕ. The price index is thus now considered as the numeraire.

The first column in table 3 reports the impact of these shocks on the main macro variables of the model. Shock to population has no impact on the economy as we assume for the present study a unitary income elasticity for consumers in the historical simulations. The decrease in tariff rates from 1990 to 2001 has little impact on the economy as the major decrease comes from agriculture which has an output share in total production less than 2%. The increase in the absolute price level has no impact on real variables but only on

Table 2: Sketch model

Step	Equation	$X^{H\bar{D}}$	$X^{\bar{H}D}$
0	$GDP = C + I + G + X - M$	P	ϕ
1	$C/G = \psi^{\mathrm{C/G}}$	G	$\psi^{\mathrm{C/G}}$
2	$C + G = \psi^{\mathrm{C/GDP}} \cdot GDP$	C	$\psi^{\mathrm{C/GDP}}$
3	$M = m\left(GDP, \bar{P}^{M}/\phi, \Upsilon^{\mathrm{src}}\right)$	M	Υ^{src}
	with $m_{GDP} > 0,\quad m_{\phi} > 0$ and $m_{\Upsilon} > 0$		
4	$I/K = \psi^{\mathrm{I/K}}$	I	$\psi^{\mathrm{I/K}}$
5	$X = x\left(\bar{P}^{X}/\phi, \Upsilon^{\mathrm{dst}}\right)$	X	Υ^{dst}
	with $x_{\phi} < 0$ and $x_{\Upsilon} > 0$	ϕ	A
7	$K/\bar{L} = k\left(R\bar{O}R, 1/A, \phi, \Upsilon^{\mathrm{prim}}\right)$	K	Υ^{prim}
	with $k_{A} < 0,\quad k_{\phi} > 0$ and $k_{\Upsilon} < 0$		
8	$GDP = 1/A \cdot f(K, \bar{L})$	GDP	A^{ID}
	with $f_{A} < 0$ and $f_{K} > 0$		

the different prices of the economy. In particular, the increase in price index decreases approximately by the same amount the exchange rate since it is defined in foreign currency per unit of Swiss franc.

Step 1 - Public consumption

In the first step, we introduce information on the structure and overall quantity of public consumption. This means that we observe the commodity composition of public consumption. However, as there is only one domestic good in the sketch model, only the movement in aggregate public expenditure can be used as example. To accommodate this information, government spending G are exogenized and the ratio of real private to real public consumption $\psi^{\mathrm{C/G}}$ is endogenized.

Results in the second column of table 3 show the effects of the shocks from step 0 plus the shock to public consumption applied in this step. We can see that the 16.14% increase in aggregate real government spending from 1990 to 2001 generates a decrease in private consumption of 2.34% (from 0.02% to -2.32%) and an extra 0.86% increase in aggregate capital (from 0.21% to 1.07%). The former is explained by the constant average propensity to consume out of GDP and the size of private consumption relative to public consumption. The reason for the latter is highly capital-intensive government spending relative to private consumption expenditure.

This first step in historical simulations allows us to estimate a first variable that is naturally exogenous but unobservable. As mention earlier, the ratio of real private to real public consumption $\psi^{\mathrm{C/G}}$ is endogenous and its resulting value in this step is equal to -15.90%. This large value is explained mainly by

Table 3: Macro results from historical simulations for 1990 to 2001 (percentage changes)

Variables	Step 0	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Real GDP	0.06	0.22	-0.71	0.05	0.05	13.23	13.01	13.13	13.23
Real investment	0.21	1.07	-2.77	-3.04	-3.00	-3.00	-3.00	-3.00	-3.00
Real private consumption	0.02	-2.32	15.74	15.77	15.77	15.64	15.60	15.56	15.67
Real public consumption	0.02	16.14	16.14	16.14	16.14	16.14	16.38	16.13	16.12
Real exports	0.38	-0.83	-18.76	8.91	8.92	55.10	54.80	55.11	55.04
Real imports	0.44	-0.54	-1.17	50.77	50.77	50.81	50.82	50.81	50.81
Aggregate employment	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75	3.75
Aggregate capital	0.21	1.07	-2.77	-3.04	-3.03	7.28	8.12	-2.22	-2.22
Average prim-fac-using tech change	0.00	0.00	0.00	0.00	0.00	-9.71	-6.73	-9.00	-9.17
Real devaluation	0.04	-0.07	-2.71	14.14	14.13	-27.38	-26.62	-27.63	-27.97
Exchange rate	-18.29	-18.20	-15.71	-29.32	-29.32	14.81	14.81	14.81	14.81
Price deflator for GDP	22.34	22.33	21.95	23.95	23.96	19.94	18.69	20.35	20.92
Price deflator for investment	22.20	22.19	22.05	22.61	22.61	19.78	13.56	18.05	20.82
Price deflator for consumption	22.37	22.37	22.37	22.37	22.37	22.37	22.37	22.37	22.37
Price deflator for public consumption	22.47	22.47	22.32	23.17	23.17	20.59	24.17	28.58	27.23
Real wage for consumers	0.25	0.25	-0.04	1.52	1.53	13.28	8.87	13.39	13.64
APC out of GDP	0.00	0.00	17.02	14.41	14.40	4.02	5.81	4.73	4.06
C/G ratio	0.00	-15.90	-0.35	-0.32	-0.32	-0.43	-0.67	-0.50	-0.39
I/K ratio	0.00	0.00	0.00	0.00	0.03	-9.58	-10.29	-0.80	-0.80

the large increase in government spending and to a less extend by the small decrease in private consumption.

Step 2 - Private consumption

The second step allows us to impose the change over the period 1990 to 2001 in the commodity structure and overall quantity of private consumption. Therefore consumption by commodity and aggregate consumption is exogenized, which enable us to endogenize consumer preferences and to free the link between the sum of private and public consumption and GNP. In terms of the sketch model, this means exogenization of aggregate private consumption C and endogenization of the average propensity to consume $\psi^{\mathrm{C/GDP}}$ as there is only a single locally produced and consumed good.

The information on movements in consumption by commodity has a strong positive effect on aggregate private consumption (from -2.77% to 15.74%) as commodity expenditure increase for most of them. The increase in global consumption has minor effects on the components of the GDP identity except from exports on which it has a major negative impact. The decline in exports relative to imports implies a deterioration of the balance of trade and a decrease in the exchange rate. As the price index for capital goods increases relative to the price index for domestic goods, aggregate capital decreases which reduces aggregate investment.

Historical simulations generate estimates of changes in household preferences for a given commodity. They are residuals of the difference between the effective percentage change in consumption per household of a given commodity and the percentage change implied by the model given movements in household consumption, prices and income for 1990 to 2001. In other words they give a measure of changes in household preferences not explained by theory embedded in the model. An estimation of 1 for a given commodity means a 1 percent growth rate of consumption per household for this good higher than would be expected on the basis of changes in total expenditure per household and changes in prices.

Results of the estimation of changes in household preferences between 1990 and 2001 are reported in column 1 in table 4. It gives the contribution of a change in household preferences for a given commodity to growth in output of this commodity. These results quantify the strong shift in household preferences in favour of health and insurance across the period 1990 to 2001 which appear with a large positive entry. On the other hand, households reduce their interest between 1990 and 2001 in primary goods, hotels and restaurants as well as in manufacturing products. Overall, there is a shift in households preferences between 1990 and 2001 from primary and secondary sectors towards services sectors.

Finally, in this step we know that aggregate private consumption increases across the period 1990 to 2001. This has naturally an impact on the ratio of real private to real public consumption estimated in the previous step. As private consumption declines relative to public consumption between 1990 and 2001, the historical simulation generates a negative value for the percentage change

Table 4: Results on commodities from historical simulations for 1990 to 2001

	Contribution (%) to Swiss output growth of changes in				Primary-factor technical progress	Capital/ labour bias
	H'hold pref.	Interm. demand	M/D ratio	X/D ratio		
	(1)	(2)	(3)	(4)	(5)	(6)
Primary goods	-2.53	-15.04	24.15	-2.77	9.39	-15.17
Manufacturing products	-1.62	2.97	65.95	73.46	3.61	-63.99
Energy	-0.68	8.15	6.29	11.04	3.03	-26.67
Construction	0.10	-21.78	-0.06	0.61	2.69	127.20
Wholesale and retail trade	-2.96	-5.46	0.06	11.03	8.62	75.42
Hotels and restaurants	-3.82	-16.02	13.44	38.36	-1.09	144.23
Transport and communication	4.11	6.11	15.82	21.96	5.27	-49.37
Financial intermediation	2.75	12.92	0.31	21.38	18.61	-8.28
Insurance	16.82	11.47	-4.22	36.51	1.03	-86.53
Business services	2.64	-0.43	0.28	1.18	1.12	186.55
Public administration	0.30	4.80	0.00	0.46	-1.06	-31.17
Education	-0.21	-3.33	0.00	0.00	5.62	192.05
Health	18.46	-10.74	2.11	2.44	7.20	85.57
Other services	-3.85	-23.65	-3.02	2.04	12.22	132.32

in the ratio of real private to real public consumption.

Step 3 - Imports

In this step we observe the movement in aggregate imports by commodity. The import observations are therefore accommodated by endogenization of twist variables in the import/domestic preferences of industries, capital creators and households. This means in terms of the sketch model exogenization of imports M and endogenization of the import/domestic preference variable Υ^{src}.

Application of the shocks for imports by commodity results in a large increase of aggregate imports. This increase in imports has little effect on GDP, capital and investment. As the sum of private and public consumption is a fixed share of GDP, the main effect of the decrease in imports is a large increase in exports (from -18.76% to 8.91%). This increase in exports is accompanied by a decrease in the exchange rate.

Estimates of import/domestic preference variables are computed as the difference between the actual percentage change in the import/domestic ratio and the percentage change implied under the theory. In addition to standard theory, the latter allows for demand pressures. It captures the idea that when output of a given commodity in the domestic economy is growing rapidly, there is a tendency for demand shifts to occur towards imports. This is explained by shortages and lengthening queues and is unrelated to movements in relative prices. Similarly, when output of a given commodity is growing slowly there is a tendency for shifts to occur towards the domestic product. Estimates of import/domestic twists take account of changes that can not be explained by changes in relative prices and demand pressures.

Results in column 3 of table 4 show the percentage contributions of the import/domestic preference shifts to sales in Switzerland of domestic commodities. Most commodities have positive entries for the period 1990 to 2001. This means that twists against imports occur for these commodities. The largest bias in favour of the domestic variety occurs for manufacturing products. Primary goods experience a large twist in preferences also towards domestic goods, as it is the case for hotels and restaurants, transport and communication. Biases in favour of imports across the period 1990 to 2001 are present only in insurance and other services.

Step 4 - Investment

The fourth step is to incorporate in the model information on investment between 1990 and 2001. The lack of data does not allow us to introduce movements on investment in each industry. This means that we can tie down only aggregate investment I. This is done by allowing the ratio of investment to capital $\psi^{\mathrm{I/K}}$ to be determined endogenously.

The introduction of the small increase in aggregate investment for 1990 to 2001 has no impact on GDP and capital since labour, technology and rates of return are assumed to be fixed. In addition, the increase is so small that, under consumption linked to GDP and imports given in the previous step, it does not affect exports and the exchange rate.

In this step, historical simulations produce an estimate of the ratio of investment to capital between 1990 and 2001. Its value of 0.03% reflects the decrease in aggregate capital stock relative to investment.

Step 5 - Exports

Here we use information on exports. This allows us to exogenize exports by commodity and to endogenize the twist variables in the export/domestic technology of industries. In terms of the sketch model this means exogenization of exports X and endogenization of the export/domestic technology variable Υ^{dst}.

However, in using export observations to estimate the shift variable exports versus locally used goods, we found indeterminacy between this shift term and the exchange rate. The problem is that an increase in exports can be explained either by an increase in the export/domestic twist shift variable or by an decrease in the exchange rate. However an decrease in the exchange rate implies an decrease in capital and so a decrease in GDP which creates an infeasibility in the GDP identity. The solution to this problem is to introduce information on the exchange rate. In order to be able to exogenize the exchange rate, we need to give the supply of export freedom to make the observed movement in exports compatible with the demand function for exports. This requirement is satisfied through the endogenization of a technology variable. In terms of the sketch model we need thus to exogenize the exchange rate ϕ and endogenize the primary-factor-using technical progress variable A.

Comparison of steps 4 and 5 in table 3 shows that movements of exports by commodity are accommodated by both a substantial demand shift reflected in huge twists in favour of exports (see below) and a supply shift reflected in primary-factor-using technical change[6] of -9.71%. The increase of 9.71% in technological progress and the increase of 10.31% in capital, induced by a appreciation of the Swiss franc and by the improvement in technology, contribute both of them to the increase of 13.18% in GDP. The large increase in capital has also an impact on real wage for consumers (from 1.53% to 13.28%) and on the ratio of investment to capital (from 0.03% to -9.58%). The former rises reflecting the increase in the capital/labour ratio and the consequent increase in the marginal product of labour. Regarding the latter, it is negative indicating the rapid growth in aggregate capital relative to aggregate investment across the period 1990 to 2001.

As in the case of imports, the export/domestic technology variable acts like a residual. Estimation of its value is the difference between the actual percentage change in the export/domestic ratio and the percentage change implied under the standard theory. A positive value means thus a twist towards exports not explained by changes in relative prices.

The percentage effects on output growth of the export/domestic technology shifts are given in column 4 of table 4. Positive entries mean twists in favour of exports from from 1990 to 2001. With one exception, results show a twist towards exports for all commodities. These upward shifts in the export demand curves are consequence of growth in the rest-of-world economy. The exception is primary goods which shows a small twist toward domestic products. A possible explanation is the large reduction of over 60% in export subsidies under the reform of the agricultural policy.

The contribution of the twist toward exports to output growth is highest for manufacturing products. Large twists towards exports occur for hotels and restaurants, as well as for insurance. Financial intermediation, transport and communication, wholesale and retail trade, and energy are examples of twists towards exports across this period but of a smaller intensity.

Step 6 - Employment

In this step we introduce information on employment. In terms of the sketch model this raises no macro closure issues since employment is already exogenous. However in the disaggregated model, observations on employment by industry allow estimation of shifts at the industry level in primary-factor technical change.

On comparing the results in table 3 for step 5 with those for step 6, we see that the imposition of the labour shocks increases aggregate employment substantially. From all the previous steps we know that the increase in employment can have little effect on GDP since all its components are approximately fixed. As GDP does not change, the primary-factor technical change increases from -9.71% to -6.73%. If it were to decrease, it would contradict equation S-7

[6] A negative value of one for the change in the technology variable decreases primary-factor inputs per unit of GDP by one per cent. With primary-factor inputs held constant, GDP increases by one per cent. A negative change for the technology variable has thus a positive impact on GDP and on capital.

as the capital decrease required to keep GDP constant in equation S-8 implies an increase in the technology variable. Although the primary-factor technical change increases, the impact on capital from steps 5 to 6 is positive due to the sufficiently large increase in aggregate employment which makes the change in the ratio of capital to labour negative. Finally, the increase in employment has a negative impact on the marginal product of labour and thus on real wage for consumers which decreases from 13.28% to 8.87%.

Column 5 in table 4 reports a measure of primary-factor technical progress. For each commodity, it is defined as the increase in output equal to the share of primary factors in a given industry's costs multiplied by the value of the technical change. The latter accounts for the difference between the actual percentage change in primary-factor input to a given industry and the percentage change in this industry's output[7]. With two exceptions, results show a positive entry indicating technical progress. The largest increase is in financial intermediation (18.61%) followed by other services (12.22%). Primary goods, wholesale and retail trade, and health experience technical progress around 8.5% from 1990 to 2001. To a less extend, technological progress is also present in manufacturing products, energy, construction, transport and communication, as well as in education.

Step 7 - Capital

The introduction of movements on capital in each industry is the focus in this step. Capital variation in each sector is accommodated by allowing a capital/labour technology twist variable to move. In terms of the sketch model we require exogenization of K and endogenization of Υ^{prim}. A positive value will favour labour whereas a negative value will favour capital. Capital/labour twists in technology are cost neutral in the sense that they do not affect a given industry's total inputs per unit of activity. In the sketch model, exogenization of capital amounts to turn off equation S-7 by the endogenization of this twist variable.

Results for step 7 in table 3 show that the application of the capital shocks decrease aggregate capital by 10.34% compared to step 6. As GDP and labour are fixed, the decrease in capital with respect to the previous step implies an increase in technical progress and an increase in real wage for consumers. This is reflected in the results by the decrease in the technology variable from -6.73% in step 6 to -9% in step 7 and by the increase from 8.87% to 13.39% in real wage.

Capital-labour biases in technology act in a similar way to import-domestic biases in preferences or to export-domestic biases in transformation technology. They account for the difference between the actual percentage change in the capital/labour ratio in a given industry and the percentage change explained by the movements in this industry's unit costs of using labour and capital. A negative value means that the industry's technology changes so that at any

[7]The model assumes a Leontief production technology to combine each commodity input and primary-factor input. This means that primary-factor composite is not sensitive to factor prices.

given ratio of the wage rate to the rental rate on capital, the industry chooses a capital/labour ratio higher in 2001 than in 1990.

From 1990 to 2001, the last column of table 4 reports huge twists in technology in favour of labour for education and business services. A plausible cause is the low level of interest rate in Switzerland during this period. Large twists favouring labour occur also in hotels and restaurants, construction and other services. On the other hand, manufacturing products, transport and communication, and insurance present large twists in technology in favour of capital across the period 1990 to 2001.

Step 8 - Production

The last step allows the model to take account of information on output changes by commodity[8]. Shocks to supply of domestic good are absorbed by a uniform (across industries) endogenously determined movement in a commodity-using technical change variable for current production and capital creation. This approach allows the model to increase the use of commodities that experience rapid growth in supply and conversely reduce the use of commodities that experience slow growth in supply. However, in order to avoid industries expanding (reducing) their use of goods per unit of output without reducing (increasing) their use of other inputs per unit of output, we allow for a cost-neutralizing endogenous movement in an all-input-saving technology variable. This means for instance that a 20 per cent input-using technical change in a given commodity required to absorb the observation on output implies a 2 per cent all-input-saving technical change in a given industry if 10 per cent of this industry's costs were accounted for by inputs of the commodity.

Results of this final step in the last column of table 3 show almost no movement in aggregate variables. From all the previous steps, GDP, labour and capital are fixed leaving the additional information from this step to be embedded in the commodity-using technical change variable.

Column 2 of table 4 shows the contributions to growth in sales of domestic products of input-using technical change in production and capital creation. Estimate of input-using technical change accounts for the difference between the actual percentage change in the sales of a given commodity to the domestic industries and the percentage change explained by movements in production and capital-creating activities of industries using this commodity. Results show that the use per unit of output of primary goods, construction, hotels and restaurant, health and other services decline substantially from 1990 to 2001. However commodity-using technical change substantially stimulates output growth of financial intermediation and insurance across this period. To a less extent, it is also the case for energy as well as for transport and communication.

[8]Although intermediate demand is not explicitly represented in the sketch model, this final step would mean exogenization of GDP and endogenization of a technical change variable in intermediate demand, A^{ID}.

5 Decomposition simulation

As explained in section 3, decomposition simulations allows us to decompose history into the parts attributable to changes in variables such as those identified in table 5. Most of these variables (e.g. technology and taste variables) are naturally exogenous variables and changes in these variables across the period 1990 to 2001 are estimated in historical simulations. Applying shocks in the decomposition simulation identical to theses estimated changes in naturally exogenous variables generate values for naturally endogenous variables identical to those specified in the historical simulation. However, since technology and taste variables are exogenous in the decomposition simulation, questions about the effects of changes in these variables can be answered.

The decomposition analysis is presented first in terms of the macroeconomic results. In the first subsection they are explained according to each relevant group of variables listed in column in table 5. The second subsection gives an analysis across theses groups of variables to find out factors underlying the macroeconomic results. The last subsection presents sectoral results of the decomposition analysis.

5.1 Macroeconomic results

Macroeconomic results of the decomposition simulation are shown in table 5. Column 1 through 9 give the contribution of the group of variables described in each column heading to the total percentage change (the last column) in each of the endogenous variable identified in the first column. Therefore the sum of these contributions gives the total percentage change in the last column for each endogenous variable. We start by looking at each main group of exogenous variables 1 to 9 individually. We therefore omit irrelevant groups of variables such that changes in tariffs (column 2) and changes in public expenditure (column 7).

Changes in export/domestic technology

The first column in table 5 gives the effects of shifts in export versus domestic technology. Estimates of these shifts are provided in historical simulations and show, with one exception, a twist towards exports for each commodity (column 4 in table 4). This implies naturally an increase in aggregate exports which leads to an appreciation of the Swiss franc. As production is now directed more towards exports, imports rise, induced by evaluation of the exchange rate, to satisfy domestic demand. The largest twist in favour of exports are in manufacturing products which accounts for 70% of aggregate exports. Because they are labour intensive relative to production of commodities enjoying favourable shifts towards domestic consumption, there is a small reduction in aggregate capital and as well as in aggregate investment.

Another effect of the technology shift towards exports is the small reduction in real private and public consumption. The explanation lies in the negative change in nominal GDP due to the larger decrease in its price deflator than

Table 5: Macroeconomic variables: decomposition of changes from 1990 to 2001 (percentage changes)

Variables	Changes in exp/dom technology (1)	Changes in tariffs (2)	Technical change (3)	Changes in imp/dom preferences (4)	Changes in H'hold tastes (5)	Growth in employment (6)	Changes in public expenditure (7)	Other factors (8)	Total
Real GDP	0.82	0.05	8.76	-0.21	-0.50	3.83	-0.03	0.06	12.78
Real investment	-1.02	0.16	-4.85	0.21	-0.69	3.31	-0.10	-0.59	-3.57
Real private consumption	-0.72	0.02	8.76	-0.58	-0.53	3.86	-0.09	4.18	14.90
Real public consumption	-0.72	0.02	8.79	-0.59	-0.53	3.87	0.32	4.19	15.35
Real exports	49.33	0.50	21.31	-11.23	-7.39	4.89	0.07	-6.51	50.98
Real imports	48.71	0.55	12.89	-12.49	-8.17	4.68	0.02	0.86	47.04
Aggregate employment	0.00	0.00	0.00	0.00	0.00	3.75	0.00	0.00	3.75
Aggregate capital	-1.02	0.16	-4.80	0.22	-0.69	3.32	-0.10	0.13	-2.79
Average prim-fac-using tech change	0.00	0.00	-9.21	0.00	0.00	0.00	0.00	0.00	-9.21
Real devaluation	-20.67	0.04	-0.98	-4.16	-0.39	0.00	0.01	-0.65	-26.80
Exchange rate	27.00	-0.03	0.98	5.98	0.54	0.00	-0.02	-21.13	13.32
Price deflator for GDP	-1.62	-0.02	0.48	-0.40	-0.04	0.00	0.00	22.14	20.55
Price deflator for investment	-1.08	-0.14	0.32	-0.30	-0.02	0.00	0.00	22.31	21.08
Price deflator for consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.37	22.37
Price deflator for public consumption	-0.10	0.12	4.20	-0.09	-0.01	0.00	0.00	22.79	26.91
Real wage for consumers	-0.95	0.29	13.69	-0.25	-0.02	0.00	0.00	-0.04	12.73
APC out of GDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.06	4.06
C/G ratio	0.00	0.00	0.00	0.00	0.00	0.00	-0.39	0.00	-0.39
I/K ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.80	-0.80
Total trade	49.03	0.53	17.25	-11.84	-7.77	4.79	0.05	-2.96	49.08
Trade/GDP	48.21	0.48	8.49	-11.62	-7.27	0.97	0.07	-3.02	36.30

the increase in its real value. The reason for the former is the decrease in the investment goods price index following the increase in imports. As total consumption is a share of nominal GDP, both private and public consumption decrease.

An interesting result is the increase in real GDP. Sales tax is applied on all sales including on exported and imported commodities. This means that twists towards exports tend to increase GDP as there is an increase in aggregate imports to satisfy domestic demand.

Technical change

Column 3 shows the macroeconomic effects of the combined movements in several technology variables. These include primary-factor-using technical change, input-using and input-saving technical changes and capital/labour bias in technology. It follows that, with fixed employment and fixed rates of return on capital, the overall decrease in these technological variables increases GDP directly via the production function and indirectly via the increase in aggregate capital. In the results, the latter in fact decreases because it is outweighed by technology twists in favour of labour, which reduces finally the contribution of technical change to real GDP. We will come back to this issue in section 5.2.

Being a fixed share of GDP, total consumption is positively affected by the increase in GDP. Moreover, with the ratio of real private to public consumption held constant, both real private and public expenditure increase. Finally, as the ratio of investment to capital is fixed, the decrease in capital stock implies a decrease in aggregate investment.

Another effect of interest related to the negative value of the average primary-factor-using technical change is the positive consequence on the exchange rate. Along the lines of the sketch model, the ratio of the investment good price index P_K to the GDP price deflator P is interpreted as a decreasing function of the exchange rate. Column 3 shows indeed a larger increase in the price deflator for GDP relative the increase in the price deflator for investment resulting in the increase in the exchange rate.

A final effect of the overall technological progress across the period 1990 to 2001 is the increase in real wage rate for consumers. With the rate of return held constant and the small increase in the exchange rate, improvement in technology has a negative impact on marginal product of capital (equation 9) requiring an increase in real wage via the factor-price frontier.

Changes in import/domestic preferences

In this column we look at the impact of the shifts in import versus domestic preferences. From historical simulations we know that with the exceptions of three commodities, all changes are positive. This means that overall households increase their interest in domestic products and aggregate imports decrease substantially. With employment, the rate of return and technology held constant, there is little effect on capital and subsequently on investment. However the reduction in aggregate imports appreciates the Swiss franc which induces a decrease in aggregate exports. These two effects cancel out more or less and GDP remains almost constant.

Changes in household tastes

Column 6 shows that changes in households tastes have a small negative impact on GDP. The reason is that production of main commodities suffering adverse shifts (e.g. manufacturing products and energy) is capital intensive relative to production of goods enjoying favourable shifts (e.g. insurance, business services and health). Reduction in aggregate capital decreases GDP and is also accompanied by a decrease in aggregate investment.

The decrease in GDP is accentuated by a decrease in sale tax revenue. Manufacturing products and energy are heavily taxed relative to insurance, business services and health. Shifts in consumption against heavily taxed commodities reduce tax revenue and has a negative impact on GDP.

Another effect of the preference shift away from manufacturing products is the large decrease in imports since their imported demand is about 80% of aggregate imports. As a consequence exports decline induced by an appreciation of the Swiss franc.

Employment growth

Across the period 1990 to 2001 growth in aggregate employment is approximately 3.8 per cent. Under the small-country assumption and constant return to scale, an increase in employment only (rates of return, ratio of investment to capital and change in technology are fixed) produces an identical increase in real GDP, aggregate capital and aggregate investment in the sketch model. As there is no impact on exchange rate, change in aggregate imports vary by the same amount. With subdued growth in private and public consumption relative to GDP, this increase in employment generates an equal change in exports.

In SwissAGE, the growth in employment gives similar results compared to the sketch model. However, the variations are not fully identical since information on sectoral employment is available. It means that the economy is shocked with observations on employment by industry instead of the movement in aggregate employment.

Other factors

The last column contains all remaining variables that are exogenous in the decomposition simulation. The main shocks in column 8 are to macroeconomic ratios, such as the ratio of investment to capital and the average propensity to consume. Inflation across the period 1990 to 2001 is also embedded in this column.

In historical simulations, the ratio of investment to capital is endogenous which allows us to have an estimation of its value of -0.80%. In the decomposition we use this value to exogenously shock the change in the ratio of investment to capital as it can be seen in column 8 in table 5. The main impact of the decrease in the ratio from 1990 to 2001 is the decrease in aggregate investment.

It has more and less no impact on aggregate capital. A minor impact is the decrease in imports through the imported demand for capital creation. However this is easily outweighed by the decrease in investment and as private and public consumption remain at the same level exports increase to keep GDP constant.

Regarding the average propensity to consume out of GDP, there is a 4.06% change between 1990 and 2001. This has naturally a positive impact similar in magnitude on real private and public consumption. This increase in total consumption has a small positive impact on imports as the share of total consumption in aggregate imports is around 28 per cent. Therefore as investment varies only slightly negatively, exports decreases helped by an appreciation of the Swiss franc. The combination of these two effects on trade is a decrease in both aggregate imports and exports with little effect on the exchange rate.

The absolute price level is tied down by exogenization of the consumer price index in historical simulations. In the decomposition simulation we keep it exogenous, which means that it can be imposed the change over the period 1990 to 2001. This has naturally no impact on real variables of the economy. Only prices change positively by approximately the same amount and the exchange rate varies negatively as it is defined in foreign currency per unit of Swiss franc.

5.2 Factors underlying the macroeconomic results

Looking across the columns in table 5 allows us to provide an explanation for changes in endogenous variables between 1990 and 2001 in terms of their major underlying determinants. There are two outstanding features for the period 1990 to 2001. The first is the relative small increase in GDP and the second feature is the rapid growth in Swiss trade relative to GDP.

Mitigate growth in GDP

Economic growth is known to be weak in Switzerland. In particular, this is the case across the period 1990 to 2001 as it can been seen from the final entry in the first row of table 5. The increase in real GDP over the period is only 12.78% which represents 1.1% per year on average. The main underlying determinants of the increase in real GDP are technical change (column 3) for 8.76% and growth in employment (column 6) for 3.83%. The increase in aggregate employment is straight forward and comes from the growth in labour force. However the contribution of technical change is more subtle since four different technical changes are part of this group of variables. The group includes primary-factor-using technical change, input-using and input-saving technical change, and capital/labour bias in technology. Column 1 to 3 in table 6 shows the contribution of each of them to the total percentage change in each of the main endogenous variables.

The contribution of technical change to growth in GDP results in a positive contribution of 11.74% for the average primary-factor-using technical change, in a negative contribution of 3.66% for the capital/labour twist in technology and in a positive contribution of 0.68% for the intermediate demand technical

Table 6: Macroeconomic variables: decomposition of the technical change from 1990 to 2001 (percentage changes)

Variables	Primary-fac-using technical change	Capital/ labour bias	Interm. demand technical change	Total technical change
	(1)	(2)	(3)	(4)
Real GDP	11.74	-3.66	0.68	8.76
Real investment	6.55	-14.01	2.61	-4.85
Real private consumption	11.69	-3.61	0.68	8.76
Real public consumption	11.71	-3.61	0.69	8.79
Real exports	16.68	0.37	4.26	21.31
Real imports	12.96	-6.14	6.07	12.89
Aggregate employment	0.00	0.00	0.00	0.00
Aggregate capital	6.57	-14.00	2.63	-4.80
Average prim-fac-using tech ch	-9.21	0.00	0.00	-9.21
Real devaluation	-1.65	0.72	-0.05	-0.98
Exchange rate	1.76	-0.82	0.04	0.98
Real wage for consumers	13.75	0.02	-0.09	13.69
Total trade	14.89	-2.76	5.13	17.25
Trade/GDP	3.15	0.89	4.45	8.49

change. The overall twist in technology in favour of labour between 1990 and 2001 (see the last column in table 4 for sectoral estimates) has thus a negative impact on real GDP. Looking within the column of the twist variable shows that the increase in labour share over the period decreases aggregate capital by 14%. With fixed ratio of investment to capital this implies also a decrease of 14% in real investment. The large decrease in aggregate capital due to the change in the capital/labour ratio explains thus the smaller contribution of total technical change to change in real GDP.

Rapid growth in Swiss trade

The last row in table 5 shows the main reasons of the rapid growth in Swiss trade. It gives percentage changes in trade relative to GDP calculated by subtracting percentage changes in GDP from percentage changes in total trade. The final entry in this row reveals that trade as a share of GDP increases by 36.3% across the period 1990 to 2001. This subsection provides an explanation to this rapid growth in Swiss trade.

There are four major factors affecting Swiss trade. Two of them are positive and the other two are significantly negative. The largest contributor to growth in Swiss trade as a share of GDP is the twist in industry towards exports. Its contribution of 48.21% is in fact more than the net increase in the trade as a share of GDP. As explained in our discussion of the first column in section 5.1, shift towards exports is strongly trade expanding because strong twists favouring exports appear in heavily export-oriented industries and because of the rapid appreciation of the Swiss franc which allows strong import growth as well.

The second significant positive entry to the large increase in trade relative to GDP is technical change with a contribution of 8.49%. The decomposition of all technology variables in table 6 reveals that the change only in the technology variable affecting primary factors is not sufficient to explain movements in trade. In particular, it leads to a 16.68% contribution for real exports and to a 12.96% contribution only for real imports. Since it has also an important impact on GDP, the net impact on trade relative to GDP is small. Input-using and input-saving technical changes combined into intermediate demand technical change have a larger contribution with 4.45% since they have little effect on real GDP. The last component of technology variables is the capital/labour bias. Although it has a negative impact on trade, its contribution to the increase in trade relative to GDP is positive since it has a larger negative effect on GDP via aggregate capital.

Twists in industry and household preferences against imports contribute negatively 11.62% to growth in trade relative to GDP. As mentioned in our discussion of column 4 in section 5.1, preference twists against imports directly decrease aggregate imports and indirectly decrease aggregate exports via real evaluation of the Swiss franc.

The second significant negative contributor to growth in Swiss trade as a share of GDP is the change in household tastes between commodities. It has a negative contribution of 7.27%. The reason is that heavily imported commodities (e.g. primary goods and manufacturing products) suffer adverse shifts (column 1 in table 4). In addition these commodities show twists against imports (column 3 in table 4) which are part of the negative impact on trade described above.

5.3 Sectoral results

In this subsection we illustrate the application of SwissAGE decomposition simulations to the analysis of particular industries. Here we concentrate on the two main positive contributors and on the largest negative contributor to growth in real GDP.

The largest contributor to the growth in real GDP is financial intermediation. From 1990 to 2001, this sector shows a very large increase in output of 66.58% as indicating by the last entry of the corresponding row in table 7. The second major contributor is manufacturing industry. This sector presents a moderate increase in output of 10.14% but is the largest industry in the Swiss economy with a share of 28.5% in total production. Finally construction plays an important role over the period since the contraction of 23.12% in this sector produces the largest negative contribution to growth in real GDP.

Looking across the columns of table 7, we can identify the sources of growth or contraction for 1990 to 2001 in these three sectors. It appears that technical change is the major reason of growth or contraction. For manufacturing industries, the 15.6% contribution of technical change is in fact higher than output growth itself. This is also the case in construction but with a negative contribution of -24.76%. For financial intermediation, the 58.15% contribution of technical change is below its output growth which is explained, among others, by a 8.22% contribution of the twist favoring exports.

Table 8 gives the contribution of each technology variable included in total technical change. In the financial intermediation sector, the 58.15% contribution of total technical change is decomposed into a 34.87% contribution of primary-factor-using technical change, a -2.48% contribution of technical change in favour of labour and a 25.76% contribution of technical change in intermediate demand. It means that the large increase in financial intermediation output is explained by strong cost-reducing improvements in primary-factor productivity (34.87%) and by the strong technological change favouring the use of financial intermediation by other industries (25.76%).

Regarding manufacturing industries, the main component of the contribution of technical change is primary-factor productivity growth. It contributes 11.86% to growth in manufacturing output, whereas intermediate-input productivity contributes only 4.16%.

The picture is quite different if we look at construction, which is the largest negative contributor to growth in real GDP. The major component of the negative growth in output of construction is technical change with a negative contribution of 24.76%. The contribution of primary-factor productivity growth in this sector is positive with 6.5%. However contributions of both technical change against the use of capital within the sector (-11.94%) and technical change against the use of their products by other industries (-19.31%) are responsible for the overall large negative contribution of technical change to the decline in construction output.

The sectoral analysis suggests that there are large changes not explained by movements in production and capital-creating activities of industries using commodities as intermediate input. To a less extend, it is also the case for changes not explained by movements in industries' unit costs of using labour and capital. Their introduction into the model is important as they may either reverse the sign of total technical change (e.g. construction) or amplify the magnitude of total technical change (e.g. financial intermediation).

6 Conclusion

Analysis of economic structural change is crucial if our economic forecasts are going to be based on economic history. However, estimation of structural change parameters is not trivial since the latter are not directly observable. The methodology used in this paper is to apply a general equilibrium model. In this framework, household preferences and industry technologies are usually exogenous variables and are not observable. On the other hand, quantities and prices are naturally endogenous to the model and are directly observable. The estimation of changes in technology and consumer preferences is realized by conducting a historical simulation. In this simulation, naturally endogenous variables are swapped with usually exogenous variables. It means that the former are exogenous and the latter are endogenous in a historical simulation. Since naturally endogenous variables can be observed across a given period, it

Table 7: Sectoral outputs: decomposition of changes from 1990 to 2001 (percentage changes)

Variables	Output share in total output	Changes in exp/dom technology (1)	Changes in tariffs (2)	Technical change (3)	Changes in imp/dom preferences (4)	Changes in H'hold tastes (5)	Growth in employment (6)	Changes in public expenditure (7)	Other factors (8)	Total
Primary goods	1.85	-28.58	-0.44	3.47	11.08	-5.36	3.11	0.02	-2.00	-18.70
Manufacturing products	28.50	-0.51	0.42	15.60	3.41	-7.62	3.93	0.07	-5.16	10.14
Energy	3.35	0.09	0.19	30.70	6.70	-4.01	4.21	-0.09	-0.25	37.54
Construction	5.71	-0.98	0.11	-24.76	-0.10	-0.15	3.05	-0.10	-0.18	-23.12
Wholesale and retail trade	9.91	2.07	-0.03	-1.23	-1.19	-5.38	3.57	-0.02	0.69	-1.51
Hotels and restaurants	2.83	0.50	-0.02	-21.99	-0.58	-5.25	3.23	-0.03	0.70	-23.44
Transport and communication	6.45	-1.33	-0.08	19.04	10.30	4.09	4.15	-0.08	-0.35	35.73
Financial intermediation	7.29	8.22	-0.13	58.15	-7.45	4.01	4.71	-0.10	-0.82	66.58
Insurance	3.40	27.81	-0.42	23.32	-22.60	31.63	5.08	-0.09	1.94	66.67
Business services	16.69	0.93	-0.04	3.99	-1.30	3.75	3.82	-0.04	1.66	12.78
Public administration	3.15	-0.89	0.01	13.25	-0.72	-0.04	3.95	0.73	4.12	20.42
Education	2.75	-2.96	-0.01	3.95	-0.95	-0.66	3.62	-4.54	3.65	2.10
Health	5.00	-2.69	-0.15	-5.69	1.32	18.01	3.95	2.98	3.78	21.51
Other services	3.14	-9.97	-0.03	-17.51	-5.43	-4.56	2.87	-0.64	1.23	-34.03

Table 8: Sectoral outputs: decomposition of technical change from 1990 to 2001 (percentage changes)

Variables	Primary-fac-using technical change	Capital/ labour bias	Interm. demand technical change	Total technical change
	(1)	(2)	(3)	(4)
Primary goods	16.24	-1.27	-11.50	3.47
Manufacturing products	11.86	-0.41	4.16	15.60
Energy	17.75	-2.19	15.14	30.70
Construction	6.50	-11.94	-19.31	-24.76
Wholesale and retail trade	10.22	-4.33	-7.12	-1.23
Hotels and restaurants	-3.18	-2.02	-16.79	-21.99
Transport and communication	12.09	-2.16	9.10	19.04
Financial intermediation	34.87	-2.48	25.76	58.15
Insurance	2.46	-2.93	23.79	23.32
Business services	8.33	-4.39	0.06	3.99
Public administration	11.46	-3.58	5.38	13.25
Education	10.44	-3.49	-3.00	3.95
Health	10.68	-3.29	-13.08	-5.69
Other services	15.08	-3.71	-28.87	-17.51

is thus possible to shock them with with their actual movements and to obtain an estimation of the usually exogenous variables. Once the historical simulation has been completed, a decomposition simulation can be conducted. In this simulation, estimates of unobservable exogenous variables are used to explain structural change in the economy across the period in consideration.

The paper reports our first set of historical and decomposition results using SwissAGE. Historical simulations allow us to quantify several aspects of structural changes in Swiss industries across the period 1990 to 2001. Our major findings are an overall twist in technology in favour of labour, against capital and an overall twist in technology in favour of production destined for exports, against production destined for domestic sale.

Developments in the Swiss economy between 1990 and 2001 are explained via decomposition simulations. They reveal that growth in real GDP is mitigated because of the negative impact of the shift in technology against capital which reduces the effect of primary-factors productivity growth on real GDP. They also show that, under an appreciation of the Swiss franc, twist in technology towards production for exports contributes heavily to the rapid growth in Swiss trade relative to GDP.

Analysis of our results from the historical and decomposition simulations reveal several areas for future work. The disaggregation of the 14 industries would enhance sectoral analysis of structural change. Improvement in the model structure relative to the labour market would allow us to refine results in different skill-based occupational categories for example. Finally recognizing that income elasticities of demand are not all unity would allow to have those for food products being less than one.

Appendix

The appendix explains in details how we move from the decomposition closure to the historical closure. The partitioning of variables adopted in the historical and decomposition closures is indicated in table 1. The center of attention in implementing an historical closure from a decomposition closure is to be able to estimate technology and preference variables (components of $X^{\bar{H}D}$) once information on observable variables have been incorporated into the model (components of $X^{H\bar{D}}$). We are going to develop the historical closure in a series of 8 steps. In this process, the naturally endogenous variables for which we have data are cumulatively exogenized. The steps are designed in order to have a valid closure at the end of each step. We are thus able to perform an historical simulation at the end of each step. Comparison of results for successive simulations show the effects of the additional data introduced at each step. Before starting with the first step, we recall the decomposition closure which is used as a starting point to develop the historical closure.

Decomposition closure

The decomposition closure is a one-period long-run closure. It is based on the short-run comparative-static closure in Dixon and Parmenter (1996) except that the short-run closure has to be transformed into a long-run closure. In the long run, the sum of private consumption and public consumption is endogenous, which means that total consumption is linked to GDP via the exogenous average propensity to consume out of GDP. Capital stock in each industry is also endogenous in the long run and is determined mainly by assumptions concerning rates of return. In particular, the rate of return is assumed not to vary which sets the percentage change of the rental price of capital equal to percentage change of the cost of units of capital. Regarding sectoral investment and government spending, they are determined independently through exogenous ratios linking the former to capital used in each industry and the latter to private consumption. The cost of units of capital in each industry and the price of units of public consumption are thus endogenous. Finally, employment is assumed to be fixed, implying that employment effects are eliminated over the medium term by adjustments in wage rates across industries.

In the decomposition closure, the remaining exogenous variables are part of X^D which means that they are either endogenous, X^{HD} or exogenous $X^{\bar{H}D}$ in the historical closure. Among the former are included changes in technology, import/domestic preferences and consumer tastes. Regarding the latter, we have the population size, the c.i.f. foreign-currency prices of imports and policy variables such as tax and tariff rates.

Finally, a common feature to most general equilibrium models is that the absolute price level is not explained. In historical simulations, the absolute price level is tied down by exogenization of the consumer price index, which is thus considered as the numeraire. However, in order to exogenize it we need to endogenize another variable and a natural candidate is the exchange rate.

Step 1 - Public consumption

Following table 1 the first step is related to public consumption. Public consumption and the ratio of real private to real public consumption are specified in the model as follows:

$$x_{c,s}^{(5)} = \iota_s f_c^{5,\mathrm{dom}} + (1-\iota_s)\, f_c^{5,\mathrm{imp}} + f^{(5,\mathrm{tot})} - \left(\iota_s - S_{c,\mathrm{D}}^{(5)}\right) \Upsilon_c^{\mathrm{src}} \tag{10}$$

$$\psi^{\mathrm{C/G}} = x^{(3,\mathrm{tot})} - x^{(5,\mathrm{tot})} \tag{11}$$

where
$x_{c,s}^{(5)}$ is the percentage change in public consumption of commodity c from source s;
ι_s is binary parameter that takes the value of one for domestic good and zero for imported good;
$f_c^{5,\mathrm{dom}}$ is a variable allowing for shifts in the commodity composition of domestic government demand;
$f_c^{5,\mathrm{imp}}$ is a variable allowing for shifts in the commodity composition of imported government demand;
$f^{(5,\mathrm{tot})}$ is a variable allowing for shift in the overall government demand;
$S_{c,\mathrm{D}}^{(5)}$ is the share of domestic good in government expenditure on commodity c;
$\Upsilon_c^{\mathrm{src}}$ is a variable allowing for cost-neutral changes in preferences between imported and domestically produced good c (see the paragraph on imports);
$\psi^{\mathrm{C/G}}$ is the percentage change in the ratio of real private to real public consumption;
$x^{(3,\mathrm{tot})}$ is the percentage change in real private consumption; and
$x^{(5,\mathrm{tot})}$ is the percentage change in real public consumption.

In the decomposition closure, the commodity composition of public consumption is exogenous and the overall quantity of public consumption is endogenous, and linked to the overall quantity of private consumption. Thus, the shift variables $f_c^{5,\mathrm{dom}}$ and $f_c^{5,\mathrm{imp}}$, and the ratio of real private to real public consumption, $\psi^{\mathrm{C/G}}$, are exogenous, whereas $f^{(5,\mathrm{tot})}$ and real public consumption, $x^{(5,\mathrm{tot})}$, are endogenous. Note that real private consumption is determined by movements in real GDP, which is specified elsewhere in the model.

In the historical simulation we introduce information on real public consumption by commodity. To accommodate this information, the variables $x_{c,s}^{(5)}$ are exogenized and the variables $f_c^{5,\mathrm{dom}}$ and $f_c^{5,\mathrm{imp}}$ are endogenized. Since now public consumption by commodity is known, aggregate public consumption can no longer be exogenously linked to private consumption. Consequently, the ratio of real private to real public consumption, $\psi^{\mathrm{C/G}}$, is endogenized. Correspondingly, the overall quantity of public consumption, $f^{(5,\mathrm{tot})}$, is exogenized.

Step 2 - Private consumption

The second vector of variables in table 1 is private consumption by commodity, $x_c^{(3,\mathrm{src})}$. This variable is normally explained in CGE models but can be observed. Thus it is a member of $X^{H\bar{D}}$. To understand the choice of corresponding variable in $X^{\bar{H}D}$, we need to modify the equation explaining household demand by commodity and add two equations. These equations take the form:

$$x_c^{(3,\text{src})} - q = \varepsilon_c \left(w^{(3,\text{tot})} - q \right) + \sum_k \eta_{c,k} \cdot p_k^{(3,\text{src})} + [a_c^{(3)} - a^{(3,\text{com})}] \tag{12}$$

$$a^{(3,\text{com})} = \sum_c \left[V_c^{(3,\text{pur,src})} / V^{(3,\text{tot})} \right] a_c^{(3)} \tag{13}$$

$$w^{(3,\text{tot})} = y^{\text{GDP,N}} + \psi^{\text{C/GDP}} \tag{14}$$

where
$x_c^{(3,\text{src})}$ is the percentage change in consumption of commodity c;
q is the percentage change in the number of households;
ε_c is the expenditure elasticity of demand by households for commodity c;
$w^{(3,\text{tot})}$ is the percentage change in total expenditure by households;
$\eta_{c,k}$ is the elasticity of demand for commodity c with respect to changes in the price of k;
$p_k^{(3,\text{src})}$ is the percentage change in the price to households of commodity k;
$a_c^{(3)}$ is a commodity-c preference variable;
$a^{(3,\text{com})}$ is a budget-share-weighted average of the commodity-c preference variables;
$y^{\text{GDP,N}}$ is the percentage change in gross domestic product (GDP); and
$\psi^{\text{C/GDP}}$ is the percentage change in the average propensity to consume out of GDP.

The first of the two additional equations (equation 13) is the budget-share-weighted average of the commodity-c preference variables. The inclusion of $a^{(3,\text{com})}$ on the RHS of equation 12 is necessary to prevent a possible violation of the budget constraint. If $a_c^{(3)}$ is 1 greater than $a^{(3,\text{com})}$, then the rate of growth of consumption per household of commodity c is 1 percentage point higher than would be expected on the basis of changes in total expenditure per household and changes in prices.

The second additional equation (equation 13) allows consumption to be determined by GDP and the average propensity to consume out of GDP. For example, if the percentage change in $\psi^{\text{C/GDP}}$ is set exogenously on zero, then the percentage movements in consumption and GDP will be the same.

In the decomposition closure, equations 12 to 14 are implemented with $a_c^{(3)}$ and $\psi^{\text{C/GDP}}$ as exogenous variables and with $x_c^{(3,\text{src})}$ and $a^{(3,\text{com})}$ as endogenous variables. Preference changes and the average propensity to consume are not normally explained in the model. Movements in consumption on the other hand are explained and with the commodity-c preference variables exogenous, the budget-share-weighted average of the commodity-c preference variables has to be endogenous.

In the historical simulation, information on movements in consumption by commodity is introduced to contribute to the estimation of changes in household preferences and in the average propensity to consume. Therefore, in the historical closure, we exogenize consumption, $x_c^{(3,\text{src})}$, and shock them with their observed movements between two hypothetical periods. To allow the exogenous consumption to be consistent with equations 12 to 14, we endogenize the commodity-c preference variables and the average propensity to consume. Endogenization of $a_c^{(3)}$ requires exogenization of $a^{(3,\text{com})}$ to prevent the absolute level of the movements in the commodity-c preference variables be indeterminate. Exogenization of $x_c^{(3,\text{src})}$ requires endogenization of $\psi^{\text{C/GDP}}$ to avoid a potential inconsistency between the movement in aggregate consumption (determined largely by $x_c^{(3,\text{src})}$) and GDP. With these exogenous/endogenous choices, $x_c^{(3,\text{src})}$ and $a^{(3,\text{com})}$ are members of the set $X^{H\bar{D}}$, whereas the corresponding members of $X^{\bar{H}D}$ are $a_c^{(3)}$ and $\psi^{\text{C/GDP}}$.

Step 3 - Imports

This model uses the Armington (1969, 1970) specification of import/domestic choice. For the typical agent (e.g. producers, investors and households), the percentage change in the demand from source s of commodity c is given by[9]:

$$x_{c,s,\cdot}^{(k)} = x_{c,\cdot}^{(k,\text{src})} - \sigma_c^{(k)} \left(p_{c,s,\cdot}^{(k)} - p_{c,\cdot}^{(k,\text{src})} \right) - \left(\iota_s - S_{c,\text{D},\cdot}^{(k)} \right) \Upsilon_c^{\text{src}} \tag{15}$$

where
$x_{c,s,\cdot}^{(k)}$ is the percentage change in the demand for produced good c from source s by agent k;
$x_{c,\cdot}^{(k,\text{src})}$ is the percentage change in the demand for composite good c by agent k;
$\sigma_c^{(k)}$ is the elasticity of substitution between imported and domestically produced good c for each agent k;
$p_{c,s,\cdot}^{(k)}$ is the percentage change in the price to agent k of produced good c from source s;
$p_{c,\cdot}^{(k,\text{src})}$ is the percentage change in the price to agent k of composite good c;
ι_s is binary parameter that takes the value of one for domestic good and zero for imported good;
$S_{c,\text{D},\cdot}^{(k)}$ is the share of domestic good in agent k's expenditure on commodity c; and
Υ_c^{src} is a variable allowing for cost-neutral changes[10] in preferences between imported and domestically produced good c.

We can see from equation 15 that the twist terms, Υ_c^{src}, are included in the demand for both domestic and imported commodities. We model these import/domestic twists as:

$$\Upsilon_c^{\text{src}} = \left(x_c^{(0,\text{dom})} - y^{\text{GDP,R}} \right) + f_c^{\text{twist}} \tag{16}$$

where
$x_c^{(0,\text{dom})}$ is the percentage change in domestic output of commodity c;

[9] For the sake of clarity, the dot means the industry index i for producers and investors and does not represent anything when households are concerned.

[10] Cost neutrality is imposed by including twist terms in the demand equations for both domestic and imported goods in such a way that these terms allow for the replacement of domestic goods with imported goods of equal cost to the user.

$y^{\mathrm{GDP,R}}$ is the percentage change in real gross domestic product (GDP); and
f_c^{twist} is an import/domestic twist shift variable.

The first term on the RHS of equation 16 allows for demand pressures. It captures the idea that when output of commodity c in the domestic economy is growing rapidly, there is a tendency for demand shifts to occur towards imports. This is explained by shortages and lengthening queues and is unrelated to movements in relative prices. Similarly, when output of c is growing slowly there is a tendency for shifts to occur towards the domestic product. The second term allows for twists in import/domestic ratios beyond those that can be explained by changes in relative prices and demand pressures.

In decomposition simulations, imports are explained and the import/domestic twist shift variables are exogenous. For the historical simulation, we observed the movement in aggregate imports of commodity c, $x_c^{(0,\mathrm{imp})}$. We made this compatible with equation 16 by endogenizing f_c^{twist}. Thus, $x_c^{(0,\mathrm{imp})}$ is part of the set $X^{H\bar{D}}$ and f_c^{twist} is the corresponding variable in $X^{\bar{H}D}$.

Step 4 - Investment

When investment is observed, it becomes member of $X^{H\bar{D}}$ as indicated by row 6 in table 1. To understand the choice of corresponding variable in $X^{\bar{H}D}$, we need to add an equation to the model defining movements in investment/capital ratios. This equation takes the form:

$$\psi_i^{\mathrm{I/K}} = x_i^{(2,\mathrm{tot})} - x_{\mathrm{K},i}^{(1)} \tag{17}$$

where
$\psi_i^{\mathrm{I/K}}$ is the percentage change in the ratio of real investment to the quantity of capital used in industry i (industry k's start-of-year capital stock);
$x_i^{(2,\mathrm{tot})}$ is the percentage change in investment in industry i; and
$x_{\mathrm{K},i}^{(1)}$ is the percentage change in industry i's start-of-year capital stock.

In the decomposition closure, ratio of real investment to the quantity of capital used in industry i, $\psi_i^{\mathrm{I/K}}$, is exogenous. On the other hand, industry i's start-of-year capital stock, $x_{\mathrm{K},i}^{(1)}$ is naturally endogenous and is determined mainly by assumptions concerning rates of return. Investment in industry i, $x_i^{(2,\mathrm{tot})}$, is also endogenous and is determined by equation 17. In the historical simulation we introduced information on investment in industry i. Thus $x_i^{(2,\mathrm{tot})}$ becomes exogenous and $\psi_i^{\mathrm{I/K}}$ becomes endogenous.

Step 5 - Exports

The export-demand equation exhibits infinite elasticity in foreign currency prices which means that prices are exogenously fixed by world prices. We assume that commodities destined for export are not the same as those for domestic use. Conversion of undifferentiated commodities into goods for both destinations is governed by a constant elasticity of transformation (CET) function. This specification allows us to have prices for exports, given exogenously by world prices, different from domestic prices resulting from market equilibrium. The percentage change in the supply for destination d of commodity c is given by:

$$q^{(1)}_{c,d,i} = q^{(1)}_{c,i} + \sigma^{1,\text{exp}}_{c,i} \left(p^{(0)}_{c,d,i} - p^{(0)}_{c,i} \right) - \left(\iota_d - S^{(1)}_{c,\text{D},i} \right) \Upsilon^{\text{dst}}_c \tag{18}$$

where
$q^{(1)}_{c,d,i}$ is the percentage change in the supply of commodity c for destination d by industry i;
$q^{(1)}_{c,i}$ is the percentage change in the output of commodity c by industry i;
$\sigma^{(1,\text{exp})}_{c,i}$ is the elasticity of transformation between exported and locally used good c for industry i;
$p^{(0)}_{c,d,i}$ is the percentage change in the price of commodity c for destination d produced by industry i;
$p^{(0)}_{c,i}$ is the percentage change in the price of composite good c produced by industry i;
ι_d is binary parameter that takes the value of one for domestically consumed good and zero for exported good;
$S^{(1)}_{c,\text{D},i}$ is the share of domestically consumed good in industry i's revenue on commodity c; and
Υ^{dst}_c is an export/domestic twist shift variable allowing for revenue-neutral changes[11] in transformation between exported and locally used good c.

As implied in the second row of table 1, shifts in exports versus domestic transformation are naturally exogenous. On the other hand, export volumes are naturally endogenous. For our historical simulation we have observations on the movements in aggregate export volumes, $x^{(4)}_c$. We reconcile these with equation 18 by endogenizing the export/domestic twist shift variables, Υ^{dst}_c, that is we allow the historical simulation to generate estimates of the shifts in exports versus domestic transformation. Thus, $x^{(4)}_c$ is in the set $X^{H\bar{D}}$ and Υ^{dst}_c is the corresponding variable in the set $X^{\bar{H}D}$.

Steps 6 and 7 - Employment and capital inputs

A stripped-down version of the demand equations for primary factors is the following:

$$x^{(1)}_{f,i} = x^{(1,\text{tot})}_i + a^{(1,\text{prim})}_i - \sigma^{(1,\text{prim})}_i \left(p^{(1)}_{f,i} - p^{(1,\text{prim})}_i \right) + \left(\iota_f - S^{(1)}_{\text{L},j} \right) \Upsilon^{\text{prim}}_i \tag{19}$$

where
$x^{(1)}_{f,i}$ is the percentage change in primary factor f to industry i;
$x^{(1,\text{tot})}_i$ is the percentage change in the overall level of output in industry i;
$a^{(1,\text{prim})}_i$ is a variable allowing for primary-factor-using changes in industry i's technology;

[11] Revenue neutrality is imposed by including twist terms in the supply equations for both domestically consumed and exported goods in such a way that these terms allow for the replacement of domestic goods with exported goods of equal revenue to the industry.

$\sigma_i^{(1,\text{prim})}$ is the elasticity of substitution in industry i between labour and capital;
$p_{f,i}^{(1)}$ is the percentage change in the price of factor f paid in industry i;
$p_i^{(1,\text{prim})}$ is the percentage change in the overall price of primary factors to industry i;
ι_f is a binary parameter that takes the value of one for labour and zero for capital;
$S_{\text{L},j}^{(1)}$ is the share of labour in the costs of primary factors to industry i; and
Υ_i^{prim} is a variable allowing for cost-neutral twists in industry i's technology either favoring labour (positive) or favoring capital (negative).

Equation 19 can be derived from an optimization problem in which primary factors are chosen to minimize the cost of a specified overall level of output, treating factor prices as given. In this optimization problem, the production function is Leontief in intermediate inputs and primary factors and CES in the primary-factor nest. Technology variables are exogenous in decomposition simulations. As indicated in row 4 of table 1, for the historical simulation we have observations for labour and capital in each each industry, $x_{f,i}^{(1)}$. To accommodate these observations, we endogenize primary-factor-using technical change, $a_i^{(1,\text{prim})}$, and the capital/labour twist, Υ_i^{prim}.

Step 8 - Production

The last type of variables in table 1 are output by commodity. To accommodate observations on production, we need two types of technical change. First, we need to give the model freedom to make the observed movement in the output of commodity c compatible with demands for commodity c. Second, we wish to avoid industries expanding their use of goods per unit of output without reducing their use of other inputs per unit of output. These two types of technical change variable are introduced in the composite commodity intermediate demands for current production $k = 1$ and capital creation $k = 2$

$$x_{c,i}^{(k,\text{src})} - ac_c - a_i^{(k)} = x_i^{(k,\text{tot})} \tag{20}$$

and also in the demands for primary factor composite for the second type of technical change variable

$$x_i^{(1,\text{prim})} - a_i^{(1)} = x_i^{(1,\text{tot})} \tag{21}$$

where
$x_{c,i}^{(k,\text{src})}$ is the percentage change in the demand for produced good c by agent k;
ac_c is a variable allowing for commodity-c-using technical change in all industries;
$a_i^{(k)}$ is a variable allowing for all-input-using changes in industry i's technology; and
$x_i^{(1,\text{prim})}$ is the percentage change in the demand for primary factor composite by industry i.

Equations 20 and 21 are derived from an optimization problem in which inputs are chosen to minimize the cost of a specified overall level of output, treating input prices as given. In this optimization problem, the production function is Leontief in intermediate inputs and primary factors.

The technology variables ac_c and $a_i^{(k)}$ are exogenous in decomposition simulations. As indicated in the last row of table 1, observations for production by commodity are available for historical simulations. In order to absorb these given output changes, we need to endogenize the technical change variables ac_c affecting the input of commodity c per unit of current production and capital creation in each industry. However, positive values for these variables mean that industries are expanding their usage of goods per unit of output without reducing their usage of other inputs per unit of output. This unrealistic implication is avoided by introducing (not indicated in table 1) an all-input-using technical change variable $a_i^{(k)}$ which offsets the effects on industry i's unit costs of the commodity-c-using technical change variables. This means that positive commodity-c-using technical change variables generate cost-neutralizing reductions in all of industry i's inputs per unit of output (negative all-input-using technical change variables). Similarly, negative commodity-c-using technical change variables generate cost-neutralizing increases in all of industry i's inputs per unit of output (positive all-input-using technical change variables).

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