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Price and Volume Effects of a Devaluation in Developing Countries

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Abstract

This paper develops a simple tool to assess the medium-term effects of a devaluation on domestic price and output levels in developing countries. It focuses on the formation of the wage rate and on government expenditure and tax policies under a devaluation, as the main determinants of the "pass-through" process, which is described by a simple general-equilibrium dependent-economy model. The main characteristic of the model is that a nominal devaluation will only bring the economy closer toward external and internal equilibria if it is accompanied by reductions in the real government deficit and the real wage. The insertion of key parameters, available for most countries, into the reduced form of the model permits a quick and easy quantification of both price and volume effects and allows a sensitivity analysis with respect to parameter and policy assumptions. The approach is applied numerically to five African countries.

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I. Introduction

The theoretical literature on the relationship between the nominal exchange rate and domestic prices has emphasized that devaluation per se cannot permanently change the equilibrium real exchange rate, defined as the price ratio of tradable goods versus domestic goods consistent with external and internal equilibrium. It can only produce a temporary deviation of the actual real exchange rate from its equilibrium level. Under conditions of price and wage flexibility (and hence equilibrium in labor and domestic goods markets), a real exchange rate appreciation and external resource balance disequilibrium occur when there is excess domestic spending fed by bank or foreign borrowing, typically on the side of the government. For example, government deficit spending in part leaks away directly in the form of higher imports, and in part drives up prices of domestic goods and thus raises import demand indirectly. Under these circumstances, the appreciation and resource balance disequilibrium, unsustainable for a given amount of reserves, can only be corrected by removing their cause, i.e., excess demand; a nominal devaluation can speed up the process of attaining equilibrium, but cannot have long-term real output effects (Edwards (1988); Khan and Lizondo (1987)). 1/

On the other hand, under conditions of nominal wage and price rigidity and less than full employment, a nominal devaluation can be instrumental in reducing the real wage, can shift the price ratio of tradable goods versus domestic goods toward its equilibrium level, and can have real output effects (Dornbusch (1974)). In the same vein, a devaluation can facilitate reductions in real government expenditure and increases in real government revenue, and thereby eliminate a cause of external disequilibrium, while avoiding the contractionary effect of deficit reduction.

The conclusion from the literature on the real exchange rate is that fiscal policies and the behavior of the nominal wage rate under a devaluation are crucial for the effects on real variables. Predicting these effects in practice minimally requires specifying the supply and demand relationships for tradable goods and domestic goods, the functioning of the labor market, the level of aggregate demand, and the fiscal policy stance.

In this paper a simple model is constructed to assess the medium-term effects on domestic price and output levels of a devaluation in developing countries. The formation of the wage rate and the stance of fiscal policies under a devaluation are critical for the outcome of the "pass-through" process, which is described by a simple dependent-economy model. The insertion of a few key parameters, available for most countries, into the reduced form of the model permits a quick and easy

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1/ Other recent analyses of real exchange rate behavior include Dornbusch (1982), Edwards (1988 and 1989), Edwards and Montiel (1989), Khan and Montiel (1987), and Khan and Lizondo (1987).

quantification of both price and volume effects. It also allows an examination of the sensitivity of the results to changes in key elasticities, wages, and aggregate demand and tax policies.

The remainder of this paper is organized as follows. Section II briefly reviews some empirical studies of the price impact of a devaluation. Section III presents the basic model and highlights the main policy instruments. Section IV considers empirical applications of the model; it shows simulations of exchange rate and accompanying tax, wage, and other policies under various assumptions for five African countries. 1/ Section V uses the model to estimate the degree of overvaluation of the real exchange rate vis-à-vis the equilibrium real exchange rate, that is, the rate consistent with external and internal equilibrium. Conclusions are presented in Section VI.

II. Empirical Studies of the Price Impact of a Devaluation

Empirical studies of the impact of a nominal devaluation on the domestic price level or the real exchange rate, 2/ are relatively few. They have focused on estimating a reduced-form equation explaining a domestic price or real exchange rate variable by the nominal exchange rate and a set of other structural and aggregate demand variables, such as terms of trade, foreign capital inflows, the government deficit, and domestic credit growth.

Edwards (1988 and 1989), using pooled time-series data for 12 developing countries, found that the nominal exchange rate, an excess demand variable (government deficit or credit supply), and the terms of trade had significant effects on the real exchange rate. From the estimated long-term elasticity of the real exchange rate with respect to the nominal exchange rate of about 0.6, he concludes that "...nominal devaluations can indeed be a quite powerful device to re-establish real exchange rate equilibrium [...provided] that the sources of the original disequilibrium [...] are eliminated." (Edwards (1988, p. 338)). Greene (1989), in a study of African countries for the 1978-88 period, also found a significant effect of the nominal exchange rate on the consumer price index (CPI) in an equation controlling for the money stock and the government deficit. 3/ In another study, Canetti and Greene (1991)

1/ The model has been applied to 15 more African countries.

2/ Defined here as foreign price level in domestic currency over domestic price level.

3/ The estimated elasticity of the CPI vis-à-vis the nominal exchange rate of about 0.4 is comparable with that found by Edwards, given that Edwards defined the real exchange rate as foreign prices in domestic currency over the CPI. Reformulating the dependent variable in terms of domestic prices only (i.e., the CPI corrected for import price increases, taking an average import share of 0.25) indicates for both studies an elasticity of domestic prices vis-à-vis the nominal exchange rate of about 0.2. Szymczak (1989) found a long-term elasticity for the domestic prices vis-à-vis the nominal parallel exchange rate of about 0.2, using quarterly data for four African countries (1971-86).

analyzed inflation in ten African countries for the 1978-85 period and found that exchange rate depreciation and monetary growth cause inflation, but suggested that a measure of overall macroeconomic policy stance as well as structural bottlenecks might be more important determinants of inflation in African countries.

Chhibber (1990) analyzed the pass-through coefficient of the nominal exchange rate in the domestic CPI for Ghana (1965-88) and Zimbabwe (1969-86). Controlling for real money supply, real GDP, unit labor costs (for Zimbabwe only), and the nominal interest rate on six-month deposits, he found long-term elasticities of the CPI vis-à-vis the nominal exchange rate of 0.40 for Ghana 1/ and 0.14 for Zimbabwe. An unpublished Fund study for Mexico, using quarterly data for 1980-88, found an elasticity of domestic prices vis-à-vis the nominal exchange rate of 0.30, when controlling for the minimum wage and government interest payments.

The problems with this type of reduced-form estimates are simultaneity and correlation between independent variables. Moreover, the estimated coefficients do not usually permit a determination of the values of the parameters of underlying structural relationships, such as export supply, import demand, and labor demand and supply, or of government policy responses such as government fiscal and credit policies. Therefore, the coefficients will usually reflect a combination of parameter values, the impact of government policies, and the implicit wage rate determination. 2/ Given the method of the cited empirical studies, the domestic inflation attributed to the nominal exchange rate impulse can reflect completely different underlying transmission channels, depending on how (import and wage) cost increases affect supply, how real income and relative prices affect the demand for domestic goods, and how the government spends and sets tax rates under the devaluation.

As a result of country differences in both economic structure and policies, the devaluation experiences also vary widely between countries and the reduced-form estimates obtained from cross-country and time-series studies seem to be of limited use for other cases. In order to fully capture all the economic interactions determining the price effect of a devaluation, one would have to estimate a fully specified model based on plausible behavioral relationships, which, given data and time constraints, is often impractical. Instead, one can use available empirical evidence on key elasticities, and a priori knowledge about some other parameters to numerically evaluate the price and other effects of a devaluation, while specifying the assumptions about

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1/ The parallel market rate gave the best result in Ghana.
2/ A similar point is made in Khan and Ostry (1991).

accompanying government policies, the wage rate determination, and remaining parameter values. 1/ This practical approach is followed here with the help of a simple two-sector model.

III. The Model

This model is a simple version of the real exchange rate model developed recently by Edwards (1988), with the main simplification being the use of a consumption function that does not incorporate financial assets or intertemporal considerations. This could be justified by the lack of quantified knowledge on portfolio behavior in African countries. The model focuses on assessing the impact of exchange rate, tax, aggregate demand, and wage policies on the domestic price level and the actual real exchange rate. The model also addresses the issue of determining the equilibrium real exchange rate and its response to altered domestic policies and exogenous shocks. 2/ In assessing output effects, the model incorporates some features of recent, essentially Keynesian, models of a contractionary devaluation. 3/ However, while allowing for disequilibrium in the labor market and a devaluation-induced fall in real wages, the model is essentially neoclassical in that prices of domestic goods are determined by supply and demand (allowing for substitution in both) and not by a fixed markup on costs, as assumed in those Keynesian models.

Aggregate demand, a key variable in the trade-off between price and volume effects, has only two components in our simplified approach. Private consumption demand is specified as a function of disposable household income alone; all other domestic demand is considered to be the main policy instrument, under control of the government through its own expenditure and credit and other policies. The mechanisms through which the government affects private investment remain implicit. 4/ Monetary policy is assumed to be accommodating, i.e., consistent with the targeted level of domestic demand and the projected real growth and inflation rates.

1/ Using estimated parameters in policy simulations has the obvious drawback that the behavioral responses might change over time, in particular under major policy shocks. The fact that this well known problem is not easily solved, strengthens in our view the argument in favor of using plausible behavioral parameters in a full model rather than making projections with reduced-form relationships.

2/ Neary (1988), Khan and Ostry (1991), and Edwards (1989) provide recent discussions of this issue.

3/ See Krugman and Taylor (1978), Cylfason and Schmid (1983), and Hanson (1983).

4/ The mechanisms could be credit and interest rate policy, tax incentives, trade regime and regulatory framework, and restructuring support to enterprises with sizable net foreign liabilities.

The economy produces two goods--exportable goods and domestic goods--and imports a third, which is an imperfect substitute for domestic goods. Outputs in the sectors of exportables and domestic goods are produced with fixed (and immobile) capital, homogeneous (and mobile) labor, and imported inputs. Domestic goods output includes both nontradables and import substitutes and the supply elasticity represents the average for all domestic goods, ranging from nontradables to perfect import substitutes. 1/ Using a standard approach (such as nested, two-level CES functions), one derives the supply of exports (E) and domestic goods (X) as a function of output prices (PE and PD), the wage rate (W), and import costs (PM):

Output

$$(1) \quad E = E^{o}[PE/c_1(W, PM)]^{\varepsilon E}$$

$$(2) \quad X = X^{o}[PD/c_2(W, PM)]^{\varepsilon X}$$

where the superscript o indicates base-year values, $c_i(W, PM)$ denote cost functions, and ε_E and ε_X are supply elasticities vis-à-vis price/cost ratios. 2/

Demand for labor (LD) is determined simultaneously with the output decisions by labor productivity functions of output prices and the wage rate:

Labor demand

$$(3) \quad LD = \ell_1 E (PE/W)^{\sigma 1} + \ell_2 X (PD/W)^{\sigma 2}$$

where ℓ_i represents base-year unit labor costs and σ_i elasticity of substitution between capital and labor. 3/

1/ Similarly, on the demand side the substitution elasticity of demand for imports versus domestic goods represents the average substitutability for all domestic goods, ranging from nontradables to perfect import substitutes.

2/ The cost function $c_i(W, PM)$ can be considered as the constant elasticity of substitution (CES) aggregation of wage and import costs with an elasticity of substitution σ_i and base year cost shares α_i, $1-\alpha_i$. Combining the composite input with capital at the second level implies a supply elasticity of $\varepsilon_i = [\gamma_i/(1-\gamma_i)]\sigma_i$, with σ_i elasticity of substitution and γ_i base-year share of labor plus import cost in output.

3/ For simplicity we neglect the labor demand resulting from substitution between labor and imported inputs. The error made is small if the substitution elasticities at the two levels have similar values or if labor costs are much larger than import costs. See footnote 1/ of Panel A in Appendix I.

For the supply of labor (LS) we use two alternative specifications: (a) a nonnegative function of the real wage (RW) for the case of labor market equilibrium with an endogenous real wage; and (b) perfectly elastic supply for the case of an exogenously given real wage:

Labor supply

(4a) $LS = LS^{o} (RW)^{\omega}$

or:

(4b) $RW = \overline{RW} = CPI^{\nu-1} RW^{o}$

where RW = W/CPI represents the real wage index and ω the labor supply elasticity. For the second alternative, the real wage is conveniently set by choosing a CPI correction factor or pass-through (ν). 1/

Prices of tradable goods and imported input costs are given in foreign currency terms, i.e., we make the small country assumption. Prices in domestic currency terms, defined as indexes vis-à-vis the base year are as follows:

Prices

(5a)	$PE = \overline{PE}\ NER\ TE$	price index of exportable goods
(5b)	$PM = \overline{PM}\ NER\ TM$	price index of imports
(5c)	$W = RW\ CPI$	nominal wage index
(5d)	$CPI = f_c(PD, PM, \theta)$	consumer price index
(5e)	$PG = f_g(PD, PM, \eta)$	other demand deflator
(5f)	$P = f(PD, PM, \zeta)$	total domestic demand deflator
(5g)	$RER = f_e(\overline{PE}, \overline{PM})\ NER/PD$	real exchange rate

where NER indicates nominal exchange rate index, $\overline{PE}$ and $\overline{PM}$ denote (given) world price indices, TE and TM are indices of export and import tax factors (i.e., $TE = (1 - t_e)/(1 - t_e^{o})$ and $TM = (1 + t_m)/(1 + t_m^{o})$ with t_e and t_m implicit trade tax rates), and

1/ We do not attempt to model the process through which nominal wages are set or negotiated in practice. For our purpose it is sufficient to assume that the nominal wage policy under a devaluation should allow the real wage to fall toward its equilibrium level. This implies downward nominal wage rigidity which is the crucial element in the simulations where a real wage reduction is set exogenously.

RER indicates real exchange rate. 1/ The base-year shares of domestic goods in private consumption (θ), in other demand (η), and in total domestic demand (ζ) are parameters in CES aggregates of domestic and import prices. 2/

Household income (Y) is the sum of sectoral value added after trade taxes and the government wage bill. Government wages (WC) are partially corrected for the devaluation-induced CPI increase reflected in a policy-controlled pass-through coefficient (ρ):

Income

$$(6) \quad Y = E\ PE\ v_1 + X\ PD\ v_2 + WC^{o}\ CPI^{\rho}$$

where ρ is the inflation correction for government wages and v_1, v_2 represent value-added shares in output, which for simplicity are assumed to be constant. 3/

Private consumption (C) is a function of disposable household income alone; real wealth and portfolio decisions only come in through changes in the average propensity to consume ($\overline{C}$), which could depend on the level of real wealth, the interest rate, and specific savings policies. 4/ Domestic tax--direct and indirect--is expressed as a proportion of household income:

Private consumption

$$(7) \quad C = \overline{C}\ Y\ TD$$

where $TD = 1-t_d$ tax factor, with t_d being the ratio of net domestic taxes and transfers over household income. 5/

1/ The real exchange rate in equation (5g) is defined as some average world price of tradable goods in domestic currency over the domestic goods price.

2/ Corresponding to each of the CES price functions are an elasticity of substitution and a CES aggregate of domestic and import demand volumes.

3/ Although this restriction is not fully consistent with the implicit production functions, it does not fundamentally change the analysis. The v_i can be written as a function of output prices, import prices, and the wage rate, which variables also determine demand for intermediate imports. See footnote 3/ of Panel A in Appendix I.

4/ However, empirical evidence for the type of countries under study does not indicate that household consumption is sensitive to changes in those variables. In the exercises presented below this parameter is kept constant.

5/ In the empirical application t_d includes nontax government revenue.

Other domestic demand (C) consists of government spending on goods and nonfactor services and private investment. For our purposes, this variable is set exogenously, reflecting the stance of aggregate demand policies; we abstract from private investment responses to changing profits, profit expectations, and interest rates, as well as from responses of government spending to the altered fiscal situation. 1/ To facilitate analysis, the policy instrument used here is the pass-through coefficient (ξ) for the devaluation-induced price increase of this expenditure category:

Other demand

$$(8) \quad C = G^{O} \, PG^{\xi}$$

where ξ represents the inflation correction for "other demand" and PG is the deflator for "other demand" from equation (5e).

Private consumption and other demand are allocated to domestic goods (including import substitutes) and imports according to a CES aggregation of imported and domestic goods from which the share of imports (μ) in domestic demand (D) derives as a function of relative prices:

Import share

$$(9) \quad D = C + G$$

$$(10) \quad \mu = \mu^{O} \, [PM/P]^{\varepsilon_M}$$

$$(11) \quad DD = (1 - \mu) \, D$$

where $\varepsilon_M = 1 - \sigma_M$ is the price elasticity of import share in domestic demand and σ_M is the import substitution elasticity (>0). 2/

The stance of fiscal policy, seen as an important cause of resource balance deficit and RER appreciation, is likely to change as a result of changes in tax rates and in government spending on wages and goods and nonfactor services that accompany a devaluation; the larger the fall in the government deficit under a devaluation, the lower the inflationary impact. Since we focus on the price and volume effects of a devalua-

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1/ Lizondo and Montiel (1989) extensively discuss these issues.

2/ The substitution elasticity of import demand, σ_M, is the import share-weighted average of the substitution elasticities of import demand for consumption and for "other demand" (cf. equations 5d-f). Over time, a change in the composition of demand would change this average, but for simplicity, we keep it constant here. The substitution elasticity for each type of demand will take higher values when the share of import substitutes in demand for domestic goods is higher. As shown in Section IV, a higher substitution elasticity will lead to a higher increase in prices of domestic goods under a devaluation.

tion, the size of the primary government deficit, but not its financing, is relevant here. Implicitly, the net foreign resource transfer (net borrowing minus interests) closes the investment-saving gap.

Equilibrium requires domestic demand for domestic goods (DD) and labor demand to equal supply of domestic goods and labor supply, respectively: 1/

Equilibrium

(12) $DD = X\ PD$

(13) $LD = LS$

The model equations in linearized form are described in Appendix I. The main endogenous variables are the price of domestic goods, the outputs of exportable and domestic goods, the real wage rate (under the first labor market closure), and imports. The main policy instruments are the nominal exchange rate, implicit tax rates, the real wage rate (under the second labor market closure), and the pass-through coefficients for government wages and "other demand" determining their changes in real terms. 2/ The nominal exchange rate acts as an indirect instrument to reduce real wages and the real government deficit when nominal wages and government expenditure are downwardly rigid. Key behavioral parameters, reflecting responses in the medium term (about five years), are the supply elasticities in the export and domestic goods sectors, the substitution elasticity of import demand, and the substitution elasticities between labor and other factors of production (under the first labor market closure). The structure of the economy is reflected in a set of value-added, demand, and import shares for the base year.

The model in linearized form is easily solved and permits a quick assessment of the medium-term price and volume effects of policy shocks after a new equilibrium is attained, i.e., when the lags in supply and demand responses--not modeled here--have worked out. The short-term effects and the time path to the new equilibrium are outside the scope of this analysis. The problem with linearization is that for large shocks it involves non-negligible errors, and in particular it over-

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1/ The model is easily modified into a demand-driven version in which the domestic price level is determined by an exogenous markup over costs, by replacing equation (2) for domestic goods supply by: $PD = c_2(W, PM)\ \tau$, where τ is the markup rate.

2/ As stated above, we do not attempt to explain how pass-through mechanisms and indexation rules which are crucial for the effect of a devaluation might work in practice. For the purpose of our analysis, we consider these variables as policy instruments.

estimates price, and underestimates volume, effects. 1/ This is sometimes neglected in the empirical literature that presents simulation results for linearized models. The shortcomings of the absence of lags and linearization can only be resolved by a dynamic nonlinear model. As a shortcut alternative, we have devised a method 2/ to reduce the linearization error, while maintaining the simplicity of the linearized model.

IV. Effects of a Devaluation: Simulation Exercises

To examine the price and volume response to a nominal devaluation under various accompanying policies, we assign realistic values to the model parameters for five African countries, based on the characteristics of their economies in 1989-90 and elasticity estimates from the empirical literature (Tables 1 and 2). The key parameters reflect the economic structure and vary greatly between countries. The shares of domestic goods in private consumption (θ) vary between 80 percent and 90 percent, while for other (investment and government) demand (η) these figures are 60 percent and 80 percent. The shares of private consumption in total domestic demand (δ) range between 70 percent and 85 percent; a large share implies that the government cannot easily influence aggregate demand through its expenditure and credit policies. The shares of imported input costs determine the cost-push effect of a devaluation on the supply of goods. Firm data are unavailable for most countries in the sample, but estimates indicate that import costs represent between 8 percent and 15 percent of the value of production, and wage costs between 25 percent and 30 percent for both the export and domestic goods sectors. Mineral export sectors typically use substantial imported goods and services.

The elasticities of export supply with respect to the price-cost ratio (ε_E) are weighted averages of commodity-specific--sometimes country-specific--estimates from the empirical literature (Table 2). 3/

1/ First, the linearization in this model neglects secondary or multiplicative effects, and second, it assumes the coefficient matrix, as obtained from base-year value shares and weights, as given during the adjustment process, whereas these shares should be updated from year to year as the endogenous variables move toward their new equilibrium values. These problems could be overcome--by stepwise linearization and re-evaluation of the coefficient matrix after each sufficiently small step--but only at the expense of simplicity, and such a procedure has no advantage over solving a dynamic nonlinear model.

2/ Described in Appendix III.

3/ The definition of the cost deflator in the estimated supply functions differs between empirical studies, but is often the domestic CPI. In the simulation model, the average cost of wages and imports is the relevant deflator for the supply response, but the estimates from the literature can be used, assuming that the observed CPIs were good proxies of average sectoral costs.

Table 1. Structural Characteristics and Key Elasticities of Five African Economies

	Kenya	Ghana	Morocco	Nigeria	Madagascar
	1989	1989	1989	1990	1990
Base-year shares in demand and production					
Share of private consumption in total domestic demand (δ)	0.69	0.83	0.70	0.69	0.81
Share of domestic goods in private consumption (θ)	0.88	0.87	0.86	0.87	0.87
Share of domestic goods in domestic final demand (ς) 1/	0.83	0.84	0.84	0.81	0.82
Share of export sector in value added (β_1) 2/	0.22	0.15	0.26	0.18	0.19
Share of domestic goods sector in value added (β_2) 2/	0.68	0.81	0.63	0.72	0.76
Share of government wages in value added ($1-\beta_1-\beta_2$) 2/	0.10	0.04	0.11	0.10	0.05
Share of wages in costs (wages, imports) 3/					
Export sector (α_1)	0.8	0.8	0.8	0.2	0.8
Domestic goods sector (α_2)	0.8	0.8	0.8	0.8	0.8
Supply and demand elasticities					
Supply elasticity vis-à-vis price-cost ratio					
Export sector (ϵ_E)	0.5	0.5	0.8	0.04	0.7
Traditional	0.5	0.7	0.5	0.5	0.5
Mining	--	0.2	0.1	--	--
Nontraditional and nonfactor services	0.5	0.5	1.0	1.0	0.8
Domestic goods sector (ϵ_X)	1.0	1.0	1.2	0.9	0.9
Elasticity of import share in domestic demand vis-à-vis import price average price ratio (ϵ_M)	0.5	0.7	0.2	0.5	0.7
			(In percentage)		
Trade shares and taxes					
Imports of goods and nonfactor services/GDP	28.7	25.5	30.3	24.6	28.9
Balance of goods and nonfactor services/GDP	-5.7	-9.8	-4.3	14.9	-10.3
Import tax as percent of imports of goods and nonfactor services	15	14	16	13	21
Export tax as percent of exports of goods and nonfactor services	--	9	--	68	10
Government					
Import tax/GDP (τ_1)	4.3	3.5	4.8	3.2	5.9
Export tax/GDP (τ_2)	--	1.5	--	26.9	1.8
Other net tax/GDP (τ_3) 4/	12.6	5.4	17.3	0.5	4.6
Wage bill/GDP (τ_4)	9.5	4.3	10.6	10.0	5.3
Expenditure on goods and services/GDP (τ_5)	12.6	5.9	10.6	17.4	12.8
Primary deficit/GDP 5/	-5.5	0.2	0.9	3.3	-5.8

Sources: Recent national accounts; and staff estimates.

1/ Domestic final demand excluding government wage bill; the complement is import final demand.
2/ Total value added at current market prices, excluding import taxes.
3/ Import costs are the costs of intermediate imported goods, directly or indirectly used in the sector.
4/ Other taxes net of domestic subsidies, transfers, and interest payments.
5/ Excluding foreign interest payments and transfers.

Table 2. Survey of Empirical Estimates of Price Elasticities

Panel A. Elasticities used

Export supply

Coffee	0.4	Vanilla, cloves	0.5	Wood	0.5	Phosphates	—
Cocoa	0.7	Vegetable oil	0.8	Fish	0.8	Gold	0.2
Tea	0.1	Cereals	0.6	Manufactures	1.0	Petroleum products	—
Cotton	0.8	Livestock	0.5	Services and others	0.5	Other minerals	—
Groundnuts	1.0	Hides and skins	0.5				

Import demand

Own compensated price elasticity of import (volume) demand vis-à-vis import price/average domestic price ratio (range): -0.3/-0.5

Panel B. Empirical estimates of production and trade elasticities

Export supply 1/

Agricultural commodities	Cross-country estimates	Country-specific estimates	Representing more than 5 percent of exports
Coffee	0.44 Africa 2/, 0.53 3/, 0.03 4/	1.2 Kenya 5/	Côte d'Ivoire, Cameroon, Kenya, Madagascar
Cocoa	0.79 3/	0.8 Ghana 6/, 0.6 Nigeria, 0.8 Côte d'Ivoire, 1.8 Cameroon 7/	Ghana, Nigeria, Côte d'Ivoire, Cameroon
Cotton	0.89 3/, 0.8 4/	0.28-0.67 Nigeria 8/	Côte d'Ivoire, Cameroon, Nigeria
Tea	0.13 3/		Kenya
Groundnuts and vegetable oils	1.06 3/	0.24-0.79 Nigeria 9/	Senegal
Food, vegetables	0.92 3/		Morocco
Cereals		0.73 (0.57) 3/	Morocco
All agriculture	1.35 10/	0.13 Côte d'Ivoire, 0.54 Senegal, 0.34 Ghana, 0.16 Kenya, 0.14 Madagascar 11/	
Other primary commodities			
Phosphates	0.10		Senegal, Morocco
Oil	—		Cameroon, Nigeria
Gold	0.20		Ghana
Other minerals	0.27 12/		
Semiprocessed commodities			
Fish	0.75 13/		Senegal, Côte d'Ivoire
Wood	0.5 14/		Côte d'Ivoire, Cameroon
Rubber	0.31 3/, 0.4 4/		Côte d'Ivoire
Petroleum (products)	— 3/		Côte d'Ivoire, Cameroon, Senegal, Kenya, Nigeria
Processed food	...		Morocco, Kenya, Côte d'Ivoire, Ghana
Textiles	1.0 13/		Morocco, Kenya, Côte d'Ivoire, Senegal
Other manufactured	...		
All exports	0.8-1.0 Sub-Saharan Africa 10/ 0.5-1.0 Sub-Saharan Africa 16/ 0.7-1.3 Sample of developing countries 15/	0.47 Kenya, 0.80 Morocco 15/	
All foods	0.8 Sub-Saharan Africa 17/		
Import demand			
Elasticity of import volume demand with respect to import prices relative to a domestic price deflator	-1.15 Sub-Saharan Africa 16/ -0.95 Developing countries 19/ -0.1/-0.5 Sample of developing countries 18/	-0.8 Kenya, -0.5 Morocco 18/	
Elasticity of import share in total demand with respect to import price relative to average demand deflator	0.5-1.0 Plausible range for developing countries 20/		
Supply of domestic goods			
Substitution elasticity between labor and capital	0.5-1.5 Plausible range for developing countries		
Implied supply elasticity with respect to price-wage ratio for labor share in value added of 0.4	0.3-1.0		

Sources: Balassa, B., "Incentive Policies and Export Performance in Sub-Saharan Africa," World Development (Oxford), Vol. 18 (March 1990), pp. 383-391. Behrman, J.R., International Commodity Agreements: An Evaluation of the UNCTAD Integrated Commodity Programme (Washington: Overseas Development Council, October 1977). Bond, M.E., "Agricultural Responses to Prices in Sub-Saharan African Countries," Staff Papers, International Monetary Fund (Washington), Vol. 30 (December 1983), pp. 703-726. Bond, M.E., "An Econometric Study of Primary Commodity Exports from Developing Country Regions to the World," Staff Papers, International Monetary Fund (Washington), Vol. 34 (June 1987), pp. 191-227. Dervis, K., J. de Melo, and S. Robinson, General Equilibrium Models for Development Policy (Cambridge: Cambridge University Press, 1982). DeRosa, D.A., "Protection and Export Performance in Sub-Saharan Africa," IMF Working Paper WP/90/83, (Washington: IMF, 1990). Devarajan, S., and J. de Melo, "Adjustment with Fixed Exchange Rate: Cameroon, Côte d'Ivoire, and Senegal," The World Bank Economic Review (Washington), Vol. 1 (May 1987), pp. 447-487. Haque, N.U., K. Lahiri, and P.J. Montiel, "A Macroeconometric Model for Developing Countries" Staff Papers, International Monetary Fund (Washington), Vol. 37 (September 1990), pp. 537-559. Khan, M.S., and C.M. Reinhart, "Relative Price Responsiveness of Foreign Trade in Developing Countries," (Unpublished; Washington: International Monetary Fund, 1990). World Bank, Accelerated Development in Sub-Saharan Africa: An Agenda for Action (New York: Oxford University Press, 1981).

1/ The export supply elasticities are long term and defined with respect to the ratio of the export price in domestic currency and a deflator for domestic costs, commonly the CPI.
2/ De Vries (1975) and World Bank (1981) reproduced in Bond (1983).
3/ Askari and Cummings (1977) reproduced in Bond (1987).
4/ Behrman (1977).
5/ Ford (1971) reproduced in Bond (1983).
6/ Bateman (1965) reproduced in Bond (1983).
7/ Behrman (1968) reproduced in Bond (1983).
8/ Ori (1969) and Diejomaoh (1973) reproduced in Bond (1983).
9/ Olayide (1972) reproduced in Bond (1983).
10/ Balassa (1990), export-output ratio with respect to real exchange rate, period 1965-82, 16 countries.
11/ Bond (1983).
12/ Average calculated by Bond (1987).
13/ World Bank estimate.
14/ UNCTAD (1974) reproduced in Bond (1987).
15/ Khan and Reinhart (1991).
16/ Arize (1986), reproduced in DeRosa (1990).
17/ Shapouri and Rosen (1989), reproduced in DeRosa (1990).
18/ Khan and Reinhart (1991), calculated compensated price elasticity of import demand.
19/ Haque et al. (1990).
20/ Based on Devarajan and De Melo (1987), and Dervis et al. (1982).

The country averages shown in Table 1 vary from less than 0.1 for mineral exporting countries to 0.8 for countries with manufactured exports or price-responsive agricultural products, such as cotton and livestock. The elasticities for the supply of domestic goods (ε_X) have been given plausible values near 1.0.

The balance of exports and imports of goods and nonfactor services varies from a deficit of 10 percent of GDP for countries that are highly dependent on imports and foreign aid, to a surplus of 15 percent of GDP for oil exporters. A further structural characteristic is the base-year composition of the government primary deficit in terms of tax and expenditure categories (Table 1).

The policy shocks examined in this section are meant to illustrate the method and not to reflect actual policy measures in the countries. They are (1) a 33 percent devaluation in domestic currency terms; (2) a change in average import and export tax factors; 1/ (3) a nominal wage policy which allows a reduction in the private sector real wage of about 10 percent; (4) a reduction in the real government wage bill of about 15 percent; and (5) a modest change in real nonconsumption expenditure on goods and services (government and investment).

Below, we report on three types of simulation exercises with numerical examples for each. The first exercise assumes an exogenously given reduction in the private sector real wage, i.e., the second labor market closure. It derives the analytical solution for the domestic price increase and examines the properties of the multiplier with respect to the nominal exchange rate change. The second exercise is done for both exogenous and endogenous real wages. It calculates the solution for all the endogenous variables, in particular domestic price level, sectoral outputs, and disposable income, using the linearized model. The third exercise, done for the second labor market closure, is an attempt to partly overcome the error made in using the linearized model.

1. The reduced-form multiplier for domestic prices, linearized model

In this exercise, we assume the labor market is in disequilibrium, and the real wage is determined by a pass-through coefficient for the CPI. The reduced-form multiplier for the domestic price level vis-à-vis the nominal exchange rate can then be expressed as a function of behavioral parameters and the inflation pass-through coefficients for private wages, the government wage bill, and "other demand", reflecting realistic aggregate demand policies (equations (4b), (6) and (8)). This "black box" of the pass-through process is mathematically opened in Appendix II. 2/

1/ The import (export) tax factor is defined as 1 plus (minus) the average import (export) tax rate. In relative change: $tm = d\,t_m / (1 + t_m)$ and $te = d\,t_e / (1 - t_e)$.

2/ It is worth recalling that the numerical results in this and the following sections are subject to the linearization error, which for large policy shocks is considerable, as shown in Section IV.3.

The overall effect of a nominal devaluation (ner), and changes in trade tax rates (tm and te) is written as: $pd = \phi_1\ ner + \phi_2\ tm + \phi_3\ te$ where $\phi_i(\nu, \xi, \rho,$ par.) denote functions of pass-through coefficients ν, ξ, ρ and other parameters in the linearized model. Table 3 shows the inflationary effects of a 33 percent parity change after response lags have worked out and a new equilibrium is attained.

For realistic parameter values, a reduction in the real wage of some 10 percent, a cut in real "other demand" of about 1 percent, and small changes in trade tax rates, the impact of a 33 percent devaluation on prices of domestic goods is between 10 percent and 23 percent, depending on the country characteristics, whereas the CPI increases by 13-24 percent. The resulting improvement in the real exchange rate lies between 10 percent and 23 percent.

The reduced-form multiplier for the effect of the nominal exchange rate on domestic goods prices (ϕ_1) takes values between 0.4 and 0.7, i.e., domestic prices rise by 4-7 percent under a 10 percent devaluation. This result depends on the country's structural characteristics, in particular, the import content in demand, the share of the export sector in value added and the pass-through of price increases into "other demand." The reduced-form multiplier for the import tax rate (ϕ_2) generally varies between 0.02 and 0.20, implying that a 10 percent reduction of the tax factor, or a 40 percent reduction of an average rate of 33 percent, reduces the domestic price level by between 0.2 percent and 2 percent. This multiplier takes negative values in cases when the income effects dominate the cost effects. The reduced-form multiplier for the effect of the export tax rate takes values between minus 0.2 and minus 0.6, reflecting the deflationary impact when devaluation-induced income gains are removed through taxation.

The sensitivity of the reduced-form multipliers with respect to the pass-through coefficients and structural parameters is explored next, with the help of the point derivatives of the nominal exchange rate multiplier (ϕ_1), also shown in Table 3. For example, if the pass-through coefficient for the nominal wage (ν) rises from 50 percent to 60 percent (compensation for the CPI increase), the nominal exchange rate multiplier increases by between 0.03 and 0.04, i.e., an additional domestic price increase of between 0.3 and 0.4 percentage point for a 10 percent devaluation. If the "other demand" pass-through coefficient rises from 90 percent to 100 percent (compensation for the demand deflator), the nominal exchange rate multiplier increases by between 0.03 and 0.04, i.e., between 0.3 to 0.4 percentage point is added to the domestic price increase under a 10 percent devaluation.

The multiplier is, for the given constellation of parameters, a positive function of the share of the export sector in value added and the share of consumption in domestic demand, both reflecting the income effects on domestic prices. The multiplier increases as the substitutability between domestic and imported goods improves (i.e., the elasticity of the import share in domestic demand takes a lower value), because

Table 3. Inflationary Impact of a Devaluation in Five African Countries: Reduced Form Linearized Model

	Kenya	Ghana	Morocco	Nigeria	Madagascar
			(In percentage change)		
Policy instruments					
Nominal exchange rate (ner)	33	33	33	33	33
Import tax factor (tm)	-1	-1	-1	-1	-5
Export tax factor (te)	-	1	-	11	1
Pass-through coefficients			(In percentage)		
Nominal wage (υ)	53	51	58	26	56
Government wage (ρ)	33	31	38	6	36
Other demand (ξ)	100	98	100	95	95
Reduced-form multiplier for domestic prices			(In absolute values)		
Nominal exchange rate multiplier (ϕ_1)	0.61	0.59	0.69	0.39	0.68
Import tax factor multiplier (ϕ_2)	0.21	0.03	0.24	0.17	0.02
Export tax factor multiplier (ϕ_3)	-0.40	-0.56	-0.46	-0.22	-0.66
Total effect package 1/			(In percentage change)		
Prices domestic goods (pd)	20	19	23	10	22
Consumer price index (cpi)	21	21	24	13	23
Nominal wage rate (w)	11	11	14	3	13
Real wage rate (rw)	-10	-10	-10	-10	-10
Real exchange rate (rer) 2/	13(11)	14(12)	10(8)	23(21)	11(9)
Point derivatives of nominal exchange rate multiplier			(In absolute values)		
vis-à-vis: nominal wage pass-through (υ)	0.43	0.42	0.42	0.30	0.36
other demand pass-through (ξ)	0.40	0.38	0.30	0.31	0.40
supply elasticity exportables (ϵ_E)	0.14	0.20	0.12	0.04	0.19
Supply elasticity domestic goods (ϵ_X)	-0.12	-0.13	-0.12	-0.08	-0.16
demand elasticity imports (ϵ_M)	-0.12	-0.20	-0.07	-0.20	-0.15
export share in value added (β_1)	1.28	2.69	1.05	1.18	2.23
import share in demand ($1-\varsigma$)	0.29	0.38	0.14	0.43	0.28
consumption share in demand (δ)	0.21	0.27	0.31	--	0.36

1/ The impact on all variables is based on linearized expressions.
2/ In domestic currency terms. Defined as the nominal exchange rate index over the domestic price index (NER/PD). The real exchange rate depreciation for the nonlinearized expression is shown in parentheses.

demand shifts from imported to domestic goods. This is reflected in values of the derivative $(\partial\phi_1/\partial\varepsilon_M)$ between minus 0.1 and minus 0.2. The multiplier is sensitive to the import share in domestic demand; for given pass-through coefficients, a 10 percentage points higher share of imports increases the multiplier by between 0.01 and 0.04, i.e., between 0.1 and 0.4 percentage points is added to the domestic price increase under a 10 percent devaluation. This somewhat counterintuitive result is explained by the stronger cost-push effect of nominal wages, which are adjusted for the stronger CPI increase, as well as by the bigger substitution possibilities when the import share is larger.

The point derivative of the multiplier vis-à-vis the supply elasticity of domestic goods production is relatively small, i.e., about minus 0.10, in most cases. Since part of the improved production response is matched by higher demand through income effects, an increase in the elasticity from 1.0 to 1.1 reduces the domestic price by 0.1 percentage point under a 10 percent devaluation.

The model has the property that, when real wages, real "other demand," and tax rates are kept constant, a devaluation is neutral, i.e., has no volume effects and leaves the RER unchanged. An inflexible real wage is relevant in situations where the labor market is in equilibrium or the labor unions are strong. Simulating this case by setting all pass-through coefficients equal to unity, and assuming no changes in tax rates, gives the expected outcome, namely a unit multiplier and absence of any output effect, which result is independent of all other parameter values. 1/

2. Effects on prices, volumes, and income: solution of linearized model

a. Exogenous real wage

The second exercise involves the solution of the full linearized model (Table 4). We first maintain the assumption of an exogenous real wage (labor market in disequilibrium). 2/ The impact on domestic prices is the same as in the first exercise, i.e., between 10 percent and 23 percent, since the underlying models are identical. Real output growth varies between 0 percent and 13 percent for exports, and between 1 percent and 6 percent for domestic goods, depending in particular on supply elasticities and the pass-through assumptions for "other demand." The output increase in the domestic goods sector is less

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1/ The unit multiplier follows immediately from equation (1) in Appendix II by setting pass-through coefficients for private sector wage, government wage and "other demand" equal to unity, i.e., $\nu=\rho=\xi=1$, so that $\phi_1=1$.

2/ In this exercise, we make the real wage reduction the exogenous variable rather than the pass-through for the nominal wage (ν); the real wage reduction is, however, kept the same as in the first exercise in Section IV.1.

Table 4. Price, Volume, and Income Effects of a Devaluation in Five African Countries: Solution Linearized Model, Exogenous Real Wage

	Kenya	Ghana	Morocco	Nigeria	Madagascar
	(In percentage change; unless indicated otherwise)				
Policy instruments					
Nominal exchange rate	33	33	33	33	33
Import tax factor	-1	-1	-1	-1	-5
Export tax factor	—	1	—	11	1
Real wage	-10	-10	-10	-10	-10
Pass-through coefficients (in percent)					
Government wage	33	31	38	6	36
Other demand	100	58	100	95	95
Price effects					
Prices, domestic goods	20	19	23	10	22
CPI	21	21	24	13	23
Average costs, domestic sector	15	15	17	26	28
Average costs, export sector	15	15	17	9	16
Import costs 1/	32	32	32	32	16
Real exchange rate 2/	13(11)	14(12)	10(8)	23(21)	11(9)
Volume effects					
Export supply	8	9	13	—	11
Domestic goods supply	4	4	6	1	6
Real other demand	—	-0.5	—	-1	-1
Real competitive import demand	-2	—	-1	-10	4
Income and other effects					
Nominal household income 3/	26	25	31	12	29
Real household income	5	4	7	-1	7
Value share of imports in total demand	5	7	1	9	3
		(In percent of GDP)			
Resource balance surplus					
In foreign currency terms 4/	1.7	1.0	2.6	1.5	0.9
Government primary balance					
In foreign currency terms 5/	2.0	1.0	2.1	5.3	0.6
In current prices 6/	1.8	1.0	2.1	6.9	0.4

1/ After import tax; in domestic currency.

2/ The real exchange rate depreciation for the nonlinearized expression is shown in parentheses.

3/ Sectoral value added after trade taxes, before nontrade taxes; including government wage bill.

4/ Increase (+), in percentage points, in the surplus in foreign currency at base-year exchange rate over base-year GDP.

5/ Increase (+), in percentage points, in the government surplus in foreign currency at base-year exchange rate over base-year GDP.

6/ Increase (+), in percentage points, in the government surplus/GDP ratio in current prices.

strong than that in the export sector owing to a lower real wage reduction in terms of the output price somewhat offset by a higher supply elasticity. Real disposable income (when deflated by the CPI) rises by 0-7 percent. The import share in domestic final demand rises by 1-9 percent in most cases, reflecting the combined effect of an increase in import prices in domestic currency of about 30 percent and a reduction in import volumes, owing to substitution, of 20-29 percent.

Shortcut measures of the impact on the external resource balance and government primary balance, 1/ measured in foreign currency at base-year exchange rate in terms of base-year GDP, show improvements of 1-3 percentage points and 0.6-5 percentage points, respectively. The improvement in the resource balance is highest in countries where price responses in foreign trade are high and the supply response in nontradable goods is not so large as to generate high income effects on imports. The improvement in the government primary balance is high in countries where the increase in the implicit export tax rate is large, and there is a substantial drop in real government expenditure on goods and services.

It is interesting to examine the reduced-form coefficients of the full model. To this end we reformulate the model slightly, by making the real growth rates of the private wage, the government wage bill, and "other demand" explicit policy instruments, i.e., we no longer use inflation pass-through coefficients. We then linearize the 12 equations in these and the other exogenous variables. Despite the model's simplicity, the (12x8) matrix of reduced-form coefficients is a complicated function of many parameters and hard to interpret analytically. We therefore look at the numerical solution of the reduced-form matrices for Kenya and Ghana. The results in Appendix I, Table 1 show that the nominal exchange rate has a unit impact on all nominal variables, reflecting the linear homogeneity of the model. The real wage and real "other demand" appear to be the most powerful instruments through which the potentially inflationary impact of a devaluation can be mitigated, although they have opposite effects on output of domestic goods. Furthermore, lowering import tax rates reduces inflation and increases output in both sectors, whereas increasing domestic tax rates reduces both inflation and output in the nontradables sector, but increases exports. Raising export tax rates strongly reduces inflation, but affects both exports and nontradable output negatively.

The reduced form allows a decomposition of the domestic price effect, as illustrated in Table 5. The reduced-form impact on domestic prices of a 10 percent real wage reduction is between 7 percent and 10 percent and that of a 10 percent reduction in real "other demand" is between 7 percent and 8 percent. Similarly, 10 percent reductions of the import and export tax factors reduce domestic prices by 1-5 percent, and 5-9 percent, respectively.

1/ See equations (14) and (15) in Appendix I. Given the simplicity of the model, the estimated impacts are only rough indications.

Table 5. Reduced-Form Multipliers for the Domestic Price Level in Two African Countries

	Nominal exchange rate	Import tax factor	Export tax factor	Domestic tax factor	Real private wage	Real "other demand"	Real government wage
Kenya							
pd =	1.0 ner	+ 0.47 tm	- 0.53 te	- 1.63 td	+ 0.87 rw	+ 0.74 gr	+ 0.17 wg
	(33)	(-1.3)	(-)	(-)	(-10)	(-)	(-12)
20 percent =	33	0.6	- 0	- 0	- 8.8	+ 0	- 2.0
Ghana							
pd =	1.0 ner	+ 0.14 tm	- 0.86 te	- 3.89 td	+ 1.02 rw	+ 0.82 gr	+ 0.17 wg
	(33)	(-1.2)	(0.8)	(-)	(-10)	(-0.5)	(-12)
19 percent =	33	- 0.2	- 0.7	- 0	- 10.2	- 0.4	- 2.0

b. Endogenous real wage

We next examine the alternative labor market closure, where an endogenous real wage equilibrates supply and demand in the labor market. The supply elasticity of labor with respect to the real wage has been set at 0.10 in all cases. As this simulation requires specifying labor demand functions (equation 3), we set the substitution elasticities and base-year employment shares at plausible values. 1/ The results are shown in Table 6. As the real wage cannot decrease without a loss of labor supply, real output in the export sector can only grow at the expense of employment (and hence output) in the nontradables sector. The reduced-form multiplier is over 60 percent, i.e., a 33 percent devaluation raises domestic prices by 19-29 percent. With equilibrium maintained in the labor market, the real effect of the devaluation is entirely due to the change in tax rates and the less than full pass-through for government wages and "other demand." For initial labor market equilibrium and positive labor supply elasticity, a devaluation accompanied by a reduction in the government deficit is contractionary, i.e., the reduction of real demand leads to a fall in output of domestic goods, which is only partly compensated by a rise in the export sector. The fall in total labor demand drives down the real wage. It is the devaluation-induced reduction in the deficit that achieves a shift in relative prices in favor of exports, and away from imports, as well as a fall in real income, thereby improving the external balance. Under these circumstances, the devaluation is highly inflationary and reduces total output and employment, but can still be instrumental in reducing real government expenditure and raising export taxes. When the labor supply elasticity is zero, total employment is constant, but output shifts toward exports only if the devaluation is accompanied by a reduction in the government deficit. Otherwise, domestic prices will rise at the same rate as the exchange rate, as will nominal wages, thereby keeping the real wage constant. 2/

3. Effects on prices, volumes, and income: approximate solution of nonlinear model

The objective of this third exercise is to reduce the error involved in linearization. Although one can only solve this problem by specifying a dynamic nonlinear model, it seems useful to combine an error-approximation method with the analytical simplicity of the linearized model. The method used here, explained in Appendix III, can be characterized as midway between a linearized and a nonlinear model. The results show that linearization overestimates domestic price changes and

1/ The elasticities of substitution between labor and other factors in the export and domestic goods sectors are set at 0.3 and 0.6, respectively, and the share of the export sector in total employment is set at 0.2.

2/ The neutrality of a devaluation for constant tax rates and real government expenditure for the case of endogenous real wages is demonstrated in an exercise similar to the one in the previous section.

Table 6. Price, Volume, and Income Effects of a Devaluation in Five African Countries: Solution Linearized Model, Endogenous Real Wage

	Kenya	Ghana	Morocco	Nigeria	Madagascar
	(In percentage change; unless indicated otherwise)				
Policy instruments					
Nominal exchange rate	33	33	33	33	33
Import tax factor	-1	-1	-1	-1	-5
Export tax factor	—	1	—	11	1
Pass-through coefficients (in percent)					
Government wage	33	31	38	40	36
Other demand	100	98	100	95	95
Price effects					
Prices, domestic goods	29	28	30	19	29
CPI	29	28	30	21	28
Average costs, domestic sector	29	29	30	29	29
Average costs, export sector	29	29	30	21	29
Import costs 1/	32	32	32	32	28
Real exchange rate 2/	4(3)	5(4)	3(2)	14(12)	4(3)
Real wage	—	—	—	-3	1
Volume effects					
Export supply	2	2	2	—	2
Domestic goods supply	-1	-1	-1	-1	—
Real other demand	—	-1	—	-1	-1
Real competitive import demand	-2	-2	-2	-8	—
Income and other effects					
Nominal household income 3/	27	27	29	17	28
Real household income	-1	-1	-1	-3	—
Value share of imports in total demand	1	2	—	5	—
	(In percent of GDP)				
Resource balance surplus					
In foreign currency terms 4/	0.8	0.7	0.9	1.3	0.4
Government primary balance					
In foreign currency terms 5/	1.2	0.5	1.0	4.1	-0.3
In current prices 6/	1.1	0.5	1.0	5.0	-0.5

1/ After import tax; in domestic currency.

2/ The real exchange rate depreciation for the nonlinearized expression is shown in parentheses.

3/ Sectoral value added after trade taxes, before nontrade taxes; including government wage bill.

4/ Increase (+), in percentage points, in the surplus in foreign currency at base-year exchange rate over base-year GDP.

5/ Increase (+), in percentage points, in the government surplus in foreign currency at base-year exchange rate over base-year GDP.

6/ Increase (+), in percentage points, in the government surplus/GDP ratio in current prices.

underestimates most volume changes (Table 7). For the parameter sets used, the impact of a 33 percent devaluation on prices of domestic goods is overestimated by about 2 percentage points in the linearized case, the impact on output of domestic goods is underestimated by about 1 percentage point, and the nominal wage increase is overestimated by some 3 percentage points. The error that is due to linearization obviously becomes much larger when the amount of the devaluation is increased. For example, under a 50 percent devaluation the domestic price and nominal wage increases in Kenya would be, respectively, 35 percent and 26 percent with linearization, as against 32 percent and 20 percent with our alternative method.

V. The Equilibrium Real Exchange Rate

The model is used to obtain an estimate of the equilibrium real exchange rate (ERER). We define the ERER as the real exchange rate (RER) which--for a target level of protection and a projected terms of trade--brings the external resource balance to a level that is compatible both with the sustainable level of foreign borrowing and transfers and with internal equilibrium. The latter is defined as the situation in which economic activity is at its potential, or full-employment, level and the government deficit is compatible with the sustainable level of foreign borrowing and transfers. Assuming that--necessarily somewhat subjective--estimates for the sustainable level of foreign borrowing and transfers and the degree of unemployment of resources are available, we simulate real wage and government deficit reduction policies--achieved through a nominal devaluation cum accompanying tax and expenditure policies--that permit the economy to attain both external and internal equilibria. The resulting real exchange rate depreciation is a measure of the degree of initial overvaluation vis-à-vis the ERER. Although the two global policy instruments suffice, in principle, to attain the two targets, the corresponding equilibrium domestic price level, and hence the ERER, depend on the choice of the tax and government expenditure measures. 1/ As a result, this method of measuring RER overvaluation vis-à-vis the ERER is sensitive both to the chosen definitions of external and internal equilibria and to the choice of policy instruments to attain them. 2/

The method is illustrated for the cases of Kenya and Madagascar (Table 8). For each country, we derive the target level of the external resource balance from a target public debt/GDP ratio, the projected interest payments on public debt and private factor payments, and the

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1/ For example, the impact of a domestic tax increase on the domestic economy is different from that of a cut in government imports (Cf. Khan and Lizondo (1987)).

2/ More generally, the method also depends on the levels of other variables, held constant or not specified in the model.

Table 7. Price, Volume, and Income Effects of a Devaluation in One African Country: Reducing the Linearization Error (Exogenous Real Wage)

	Kenya		Kenya	
	Linearization	Error reduction	Linearization	Error reduction
	(In percentage change)			
Nominal exchange rate	33	33	50	50
Price effects				
Real wage	-10	-10	-10	-10
Nominal wage	11	8	26	20
Prices domestic goods	20	18	35	32
CPI	21	20	36	34
Average costs, domestic goods production	15	12	31	26
Import costs	32	31	49	48
Real exchange rate	13	13	15	14
Volume effects				
Export supply	8.4	8.9	9.1	9.5
Domestic goods supply	4.1	4.5	4.5	5.0
Real competitive import demand	-2	-1	-3	-2
Income and other effects				
Nominal household income	26	27	40	41
	(In percent of GDP)			
Resource balance in foreign currency 1/	1.7	1.5	2.1	1.8
Government primary balance in foreign currency 2/	2.0	2.3	2.4	2.7

1/ Increase (+), in percentage points, in the surplus in foreign currency at base-year exchange rate over base-year GDP.

2/ Increase (+), in percentage points, in the government surplus in foreign currency at base-year exchange rate over base-year GDP.

Table 8. Equilibrium Real Exchange Rate in Two African Countries

Base year	Kenya 1989	Madagascar 1990
	(In percent of base-year GDP)	
Objectives		
Targeted improvement in resource balance 1/	1.3	0.6
Actual resource balance 2/	-5.7	-10.3
Target resource balance	-4.4	-9.7
Target public debt/GDP ratio	50	80
Net public capital inflow 3/	3.5	5.6
Interest payments on target public debt 4/	-1.8	-0.9
Net official transfers	2.1	6.0
Net private flows	0.6	-1.1
Targeted government primary balance improvement 1/	2.1	-0.3
Actual government primary balance 2/	-5.5	-5.8
Target net foreign resource transfer	3.8	10.8
Targeted annual reduction (-) in domestic debt	-0.5	-4.7
Targeted increase in level of activity	3	10
	(In percentage change, unless otherwise indicated)	
Policy instruments		
Nominal wage	15	7
Reduction (-) in protection 5/	-20	-40
New (old) level of implicit export tax rate 6/	(--)	11 (10)
pass-through coefficient	1.0	0.8
Real "other demand"	(--)	(--)
Government wage bill	7	7
Nominal exchange rate	33	33
Results		
Prices domestic goods	21	19
CPI	22	20
Real exchange rate 7/	10	12
Resource balance in foreign currency 1/	1.3	0.7
Government primary balance 1/	2.0	-0.2
Real wage	-6	-11
Real output 8/	3	9

1/ In foreign currency at base-year exchange rate in percent of base-year GDP.

2/ Corrected for exceptional circumstances in the base year, such as sale of stocks. Corrected for effects of expected terms of trade change.

3/ Obtained from the target debt/GDP ratio and a nominal GDP growth rate of 7 percent per year.

4/ At present average borrowing conditions for the country.

5/ Reduction in the average tariff rate on imports of goods and nonfactor services.

6/ Increase in implicit export tax rate, defined as government revenue from exports over value of exports of goods and nonfactor services. The increase is achieved by allowing a less than 100 percent pass-through of the nominal exchange rate into producer prices and margins. See footnote 2/ in Appendix I on page 31.

7/ Defined as the nominal exchange rate index over the domestic price index.

8/ Weighted average of output increases in exports and domestic goods sectors.

projected levels of sustainable public and private transfers. 1/ The target external resource balance is compared with the actual resource balance in the base year after correction for exceptional circumstances in that year. In the same way, we obtain a target for the government primary balance, taking into account the desirable levels of foreign and domestic debt. The target increase in the level of economic activity follows from an analysis of the evolution of real output over the past ten years.

The illustrative simulations 2/ show that the assumed targets for resource balance, government primary balance, and output could be obtained practically with policy packages, including nominal devaluations, which result in real exchange rate depreciations of 10 percent and 12 percent, respectively, for Kenya and Madagascar.

VI. Conclusions

In this paper we have developed a simple two-sector general equilibrium model for assessing the medium-term effects of a devaluation on domestic price and output levels in developing countries. It focuses on the formation of the wage rate and the stance of fiscal policy as the main determinants of the "pass-through" process. Although the model excludes intertemporal considerations from the household consumption function, and portfolio behavior, its simplicity and minimal parameter requirement make it an easily applicable tool to simulate policy packages including a devaluation.

Empirical studies have focused on estimating a reduced-form equation, which explains the domestic price level by the nominal exchange rate, structural variables such as terms of trade, and aggregate demand variables such as government deficit and credit supply. The main problem with this type of study is that the estimated coefficients will reflect a mixture of (1) the parameters of structural relationships, (2) the levels of policy variables, and (3) the implicit wage rate determination. Since devaluation-inflation pass-through estimates obtained from such studies are in our view of limited use for other cases, we have followed an alternative approach here. This consists in fully specifying a number of structural relationships, assigning estimated or plausible values to key structural and behavioral parameters, and making assumptions on essential policy variables. Data requirements are mainly

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1/ The target level of the external resource balance depends on the assessment of what is sustainable in the long run for each country under study. In particular, the use of a target debt/GDP ratio to determine the net new public borrowing reflects solvency considerations that are difficult to quantify. Moreover, it assumes that the excess debt over and above the target level of debt is dealt with in a way (such as refinancing and/or cancellation) other than by full repayment.

2/ The results shown in this section are obtained with the linearization error reduction method.

the price elasticities of supply of exports and domestic goods, price elasticities of import demand, and the base-year structures of value added, domestic demand, and government balance. The solution of the linearized model reflects the medium-term impact of policy shocks, i.e., after lags in supply and demand responses have worked out.

The paper reports on illustrative exercises for a 33 percent devaluation for five African countries, for which data on base-year structural characteristics and key elasticities have been collected. The results strongly depend on the assumptions about the wage formation and the accompanying trade tax and government expenditure policies, and are also sensitive to the structural characteristics and behavioral parameters.

The price effects of a devaluation are most sensitive to what happens to real wages, i.e., to what extent nominal wages are indexed to the CPI. Under the assumption of unemployment and downward rigidity of the nominal wage, a devaluation is a tool to reduce the real wage toward its equilibrium level. For a 10 percent real wage reduction the medium-term impact of a 33 percent devaluation on domestic prices is between 23 percent and 25 percent, depending on country characteristics. Furthermore, a simultaneous reduction in the government real wage bill by 10 percent reduces the price impact by some 2 percentage points, whereas a reduction in the import tax factor and an increase in the export tax factor--by 1 percent each--further mitigate the inflationary effects of a devaluation by about 0.3 percentage point and 0.7 percentage point, respectively. Each percent reduction in real nonwage expenditure (mainly government) contributes to lowering the price increase by about 0.7 percentage point.

With respect to base-year characteristics and elasticities, the results are relatively sensitive to the share of the export sector in value added, the share of imports in domestic demand, and the price elasticity of import demand. The larger the share of the export sector in total value added, the larger the demand-pull effects from devaluation-induced income gains on the domestic price level. The larger the share of imports in demand, the larger the cost-push effect of nominal wages, which are adjusted for the higher CPI index (for a given reduction in the real wage), and the stronger the substitution of domestic for imported goods (for a given price elasticity of import demand). Finally, the higher the price responsiveness of imports, the higher the demand pressure on domestic production.

Real output in the export sector increases--by between 0 percent and 13 percent, depending on supply elasticities--mainly as a result of the reduction in the real wage in terms of the output price corrected for higher export taxation. Real output in the domestic goods sector increases less strongly--by 1-6 percent--owing to a lower reduction in the real wage in terms of the output price, which is somewhat offset by a higher supply elasticity in that sector.

In all countries, the reductions in the real wage and government deficit, combined with relatively conservative estimates of trade elasticities and a modest reduction in real nonconsumption demand, are sufficient to improve the external resource balance by between 1 percent and 3 percent of GDP (at base-year prices) in the medium term.

These results change drastically when the real wage is inflexible, i.e., when the labor market is initially in equilibrium or when labor unions are strong. In this case, the rate of the domestic price increase will tend to be the same as the rate of the devaluation without any output effects; however, when the devaluation induces a reduction in the government deficit, prices of domestic goods rise less quickly than the exchange rate does, resulting in a shift of production from domestic toward exportable goods, while leading to a fall in total labor demand.

In this paper, we have shown that the errors involved in solving the linearized model can be substantial and have developed an alternative shortcut solution procedure, which results in lower price and higher volume effects of a devaluation. Finally, the model is used to estimate the equilibrium real exchange rate, i.e., the rate that brings the external resource balance to a level that is compatible with a sustainable level of net foreign resource transfers and with full employment and a sustainable government deficit. We simulate policy packages aimed at attaining those targets through a devaluation, real wage reduction, and government tax and expenditure policies. The resulting real exchange rate depreciation is an estimate of the initial overvaluation vis-à-vis the equilibrium real exchange rate. Overall, the results of the simulations for five African countries are plausible and stress the crucial role of accompanying policies and key parameters in determining the "pass-through" of the devaluation into domestic prices.

The Linearized Model

Panel A gives the basic model equations in relative change with secondary effects neglected (lower case or dot denotes relative change).

After substituting equations (5a'-5c') and (5e'-5f') into the other ones, equation (13') into (4a') for the first labor market option, and after dropping equation (13') for the second labor market option, we obtain a system of 12 linear equations in 12 endogenous variables (e, x, ld, rw, pd, cpi, y, c, g, $\dot{\mu}$, d, dd).

Let B represent the (12x12) coefficient matrix of the endogenous variables, A represent the (12x6) coefficient matrix of the exogenous variables, and y and x be the vectors of endogenous and exogenous variables. The solution is found by $y = B^{-1} A x$, where x consists of the relative changes in: nominal exchange rate, import tax factor, export tax factor, average propensity to consume, domestic tax rate, and real wage (only for the second labor market option).

The impact on resource balance and government balance in current prices is written as: 1/

$$d(RB/Y) = \frac{\beta_1(1 + e + ner) - (\frac{M_o}{Y_o})(1 + \dot{\mu} + d)}{(1 + y)} - (\frac{E_o - M_o}{Y_o}) \tag{14}$$

1/ Similar formulas hold for the balances in base year-prices.

$$(15) \qquad d(GSUR/Y) = \left[\frac{\gamma_1(1 + tm' + ner + m_{vol}) + \gamma_2 (1 + te' + ner + e) + \gamma_3 (td' + y) - \gamma_4 (1 + \rho\, cpi) - \gamma_5 (1 + \psi + \xi\, cpi)}{(1 + y)}\right] - \left(\frac{GSUR_o}{Y_o}\right)$$

where: $\frac{M_o}{Y_o}$, $\frac{E_o - M_o}{Y_o}$, $\frac{GSUR_o}{Y_o}$ represent the base-year shares in GDP of imports, the export-import balance, and the government surplus excluding foreign grants and interests, respectively; m_{vol} is the growth rate of import volume; γ_1, γ_2, γ_3 are, respectively, base-year shares in GDP of import tax, export tax, and other net tax and nontax revenue; γ_4, γ_5 are the base-year shares in GDP of government wage bill and other expenditure on goods and nonfactor services; ψ is the relative change in government share in "other demand"; and tm', te', td' are relative changes in import, export, and domestic tax rates, respectively. 1/

1/ For example, $te' = d\, t_e / t_e = te\,(1-t_e) / t_e$. Cf. footnote 1/ on page 13.

Panel A Equations of the linearized model

(1') $e = \varepsilon_E [pe - \alpha_1 w - (1 - \alpha_1) pm]$

(2') $x = \varepsilon_X [pd - \alpha_2 w - (1 - \alpha_2) pe]$

(3') $ld = \lambda [e + \sigma_1 (pe - w)] + (1 - \lambda) [x + \sigma_2 (pd - w)]$ 1/

(4a') $ls = \omega rw$

(4b') $rw = \overline{rw} = (\nu - 1) cpi$

(5a') $pe = ner - te$ 2/

(5b') $pm = ner + tm$

(5c') $w = rw + cpi$

(5d') $cpi = \theta pd + (1 - \theta) pm$

(5e') $pg = \eta pd + (1 - \eta) pm$

(5f') $p = \zeta pd + (1 - \zeta) pm$

(5g') $rer = ner - pd$

(6') $y = \beta_1 (e + pe) + \beta_2 (x + pd) + (1 - \beta_1 - \beta_2) \rho cpi$ 3/

(7') $c = \bar{c} + y - td$

(8') $g = \xi pg$

(9') $d = \delta c + (1 - \delta) g$

(10') $\dot{\mu} = \varepsilon_M (pm - p)$

(11') $dd = - \dot{\mu} \frac{\mu}{1-\mu} + d$

(12') $dd = x + pd$

(13') $ld = ls$

1/ This simplification neglects the labor demand resulting from substitution between labor and imported inputs, i.e.:

$(\bar{\sigma}_1 - \sigma_1) (1 - \alpha_1) (pm - w) + (\bar{\sigma}_2 - \sigma_2) (1 - \alpha_2) (pm - w)$, where

$\bar{\sigma}_i$ is the substitution elasticity between labor and imported inputs.

2/ The relative change in the export factor ($te = d\, t_e/(1 - t_e)$, where t_e export tax rate) is--for the case of implicit taxation of agricultural and mineral exports--obtained as follows.

Let $t_e^o = (\overline{PE}\ ER - CO) / \overline{PE}\ ER$ be the base-year implicit tax rate, with CO representing total costs of producers and intermediators. Let the pass-through of the devaluation into costs be ϕ_c. Then the new implicit tax rate is:

$$t'_e = \frac{\overline{PE}\ ER\ (1 + er) - CO\ (1 + \phi_c\ er)}{\overline{PE}\ ER\ (1 + er)} = \frac{(1 + er) - (1 - t_e^o)\ (1 + \phi_c\ er)}{(1 + er)}$$

Note that $t'_e = t_e^o$ for $\phi_c = 1$, and $t'_e = (t_e^o + er)/(1 + er)$ for $\phi_c = 0$.

3/ This simplification neglects the change in value-added shares that is due to substitution of domestic factors for imported inputs. The relative changes in domestic value-added shares are:

$\overset{\bullet}{v}_i = -\frac{(1 - v_i)}{v_i}\ (1 \overset{\bullet}{-} v_i)$ where $(1 - v_i)$ are the shares of imported inputs in production, in relative change:

$$(1 \overset{\bullet}{-} v_1) = (\sigma_1 - 1)\ (pe - pm) + (\bar{\sigma}_1 - \sigma_1)\ \alpha_1\ (pm - w)$$

$$(1 \overset{\bullet}{-} v_2) = (\sigma_2 - 1)\ (pd - pm) + (\bar{\sigma}_2 - \sigma_2)\ \alpha_2\ (pm - w)$$ for the export and domestic goods sectors, respectively.

Panel B Base year shares and elasticities:

α_i	Base-year shares of wage costs in total wage and imported input costs in export and domestic goods sectors (α_i = 1, 2).
β_1, β_2	Base-year shares of export and domestic goods sectors in total value added.
$1-\beta_1-\beta_2$	Base-year share of government wage bill in total value added.
γ_i	Base-year shares in GDP of import tax, export tax, other net tax and nontax revenue, government wage bill, and other government expenditure on goods and nonfactor services (i = 1, 5).
δ	Base-year share of consumption in total domestic demand.
ε_E, ε_X	Supply elasticities vis-à-vis price/cost ratios in the export and domestic goods sectors, respectively.
ε_M	Elasticity of import share in domestic demand vis-à-vis import price/average price ratio.
θ, η, ζ	Base-year shares of domestic goods in private consumption, other demand, and total domestic demand, respectively.
λ	Base-year share of export sector in total employment.
μ	Import share in domestic demand with $\mu'=\mu/(1-\mu)$
ν, ρ	Pass-through coefficients of CPI increase into nominal wages and government wages, respectively.
ξ	Pass-through coefficient of price increase into "other demand."
σ_i	Elasticities of substitution between capital and labor (and imported inputs) in export and domestic goods sectors (i = 1, 2).
$\bar{\sigma}_i$	Elasticities of substitution between labor and imported inputs in export and domestic goods sectors (i = 1, 2).
ω	Elasticity of labor supply with respect to the real wage.
v_i	Base-year value added shares in output in export and domestic goods sectors (i = 1, 2).

Table 1. Coefficient Matrix of the Reduced Form of the Linearized Model 1/

	Nominal exchange rate	Import tax factor	Export tax factor	Households' propensity to consume	Real private wage	Real other demand	Real government wage	Domestic tax factor
				Ghana				
Prices, domestic goods	1.00	0.14	-0.86	3.89	1.02	0.82	0.17	-3.89
Real wage	—	—	—	--	1.00	—	—	—
Production, exportables	—	-0.20	-0.20	-1.39	-0.77	-0.29	-0.06	1.39
Production, domestic goods	—	-0.26	-0.26	1.17	-0.49	0.25	0.05	-1.17
Labor demand	—	-0.32	-0.32	0.70	-1.08	0.15	0.03	-0.70
Household income (excluding trade tax, including government wages)	1.00	-0.12	-1.12	4.04	0.35	0.85	0.23	-4.04
Private consumption	1.00	-0.12	-1.12	5.04	0.35	0.85	0.23	-5.04
Other demand	1.00	0.41	-0.59	2.67	0.70	1.56	0.12	-2.67
Import share in domestic demand	—	0.51	0.51	-2.29	-0.60	-0.48	-0.10	2.29
Domestic demand	1.00	-0.03	-1.03	4.63	0.41	0.98	0.21	-4.63
Domestic demand for domestic goods	1.00	-0.12	-1.12	5.06	0.53	1.07	0.23	-5.06
CPI	1.00	0.25	-0.75	3.39	0.89	0.72	0.15	-3.39
				Kenya				
Prices, domestic goods	1.00	0.47	-0.53	1.63	0.87	0.74	0.17	-1.63
Real wage	—	—	—	--	1.00	—	—	—
Production, exportables	—	-0.33	-0.33	-0.50	-0.66	-0.22	-0.05	0.50
Production, domestic goods	—	-0.20	-0.20	0.62	-0.47	0.28	0.06	-0.62
Labor demand	—	-0.29	-0.29	0.40	-0.80	0.18	0.04	-0.40
Household income (excluding trade tax, including government wages)	1.00	0.18	-0.82	1.56	0.20	0.70	0.26	-1.56
Private consumption	1.00	0.18	-0.82	2.56	0.20	0.70	0.26	-2.56
Other demand	1.00	0.67	-0.33	1.03	0.55	1.47	0.11	-1.03
Import share in domestic demand	—	0.27	0.27	-0.84	-0.45	-0.38	-0.09	0.84
Domestic demand	1.00	0.33	-0.67	2.08	0.31	0.94	0.21	-2.08
Domestic demand for domestic goods	1.00	0.28	-0.72	2.25	0.40	1.02	0.23	-2.25
CPI	1.00	0.59	-0.41	1.27	0.68	0.57	0.13	-1.27

1/ The matrix is written as $B^{-1}A$, where B and A coefficient matrices of the endogenous and exogenous variables, respectively.

Derivation of Reduced-Form Multiplier for Domestic Prices 1/

Solving the linearized model of Appendix I through substitution gives the reduced-form multiplier ("black box") for the nominal exchange rate:

(1)

$$\phi_1 = -\frac{\partial pd}{\partial ner} = -\{\alpha_1 \delta \beta_1 \varepsilon_E - (1-\alpha_2)(\delta \beta_2 - 1)\varepsilon_X - \zeta \mu' \varepsilon_M + \delta \beta_1 - \nu (1-\theta)[\alpha_1 \delta \beta_1 \varepsilon_E + \alpha_2 (\delta \beta_2 - 1)\varepsilon_X] + \rho (1-\theta)\delta (1-\beta_1-\beta_2) + \xi (1-\eta)(1-\delta)\} / \{\delta \beta_2 - 1)(\varepsilon_X + 1) + \zeta \mu' \varepsilon_M - \nu \theta [\alpha_1 \delta \beta_1 \varepsilon_E + \alpha_2 (\delta \beta_2 - 1)\varepsilon_X] + \rho \theta \delta (1-\beta_1-\beta_2) + \xi \eta (1-\delta)\}$$

Simplified as:

$$(2) \quad \phi_1 = -\frac{(a + b\nu + c\rho + d\xi)}{(e + f\nu + g\rho + h\xi)} = -\frac{\text{numerator}}{\text{denominator}}$$

Except for very low values for the pass-through coefficients, ϕ_1 is positive; it is unity for $\nu=\rho=\xi=1$, i.e., for unchanged real wages and expenditure. For a plausible range of parameter values the signs of the first derivatives of ϕ_1 take the expected values:

$$\frac{\partial \phi_1}{\partial \nu} > 0 \,, \quad \frac{\partial \phi_1}{\partial \rho} > 0 \,, \quad \frac{\partial \phi_1}{\partial \xi} > 0 \,, \quad \frac{\partial \phi_1}{\partial \varepsilon_E} > 0 \,, \quad \frac{\partial \phi_1}{\partial \varepsilon_X} < 0 \,,$$

$$\frac{\partial \phi_1}{\partial \varepsilon_M} < 0 \,, \quad \frac{\partial \phi_1}{\partial \beta_1} > 0 \,, \quad \frac{\partial \phi_1}{\partial \delta} > 0 \,, \quad \frac{\partial \phi_1}{\partial (1-\zeta)} > 0$$

1/ The relative changes in the domestic tax factor td and that in the propensity to consume c in equation (7') have been set at zero for this exercise. The corresponding reduced-form multipliers for domestic prices are negative and positive, respectively.

The reduced-form multipliers for the import and export tax factors are as follows:

$$(3)\ \phi_2 = \frac{\partial\ pd}{\partial\ tm} = -\{-(1-\alpha_1)\ \delta\ \beta_1\ \varepsilon_E - (1-\alpha_2)\ (\delta\ \beta_2 - 1)\ \varepsilon_X - \zeta\ \mu'\ \varepsilon_M$$

$$- \nu\ (1-\theta)\ [\alpha_1\ \delta\ \beta_1\ \varepsilon_E + \alpha_2\ (\delta\ \beta_2 - 1)\ \varepsilon_X\ ] + \rho\ (1-\theta)\ \delta\ (1-\beta_1-\beta_2)$$

$$+ \xi\ (1-\eta)\ (1-\delta)\}\ /\ \text{denominator}$$

$$(4)\ \phi_3 = \frac{\partial\ pd}{\partial\ te} = \delta\ \beta_1\ (\varepsilon_E + 1)\ /\ \text{denominator}$$

The import tax multiplier can be positive or negative, depending on price, income, and supply effects, and increases with the share of imports in demand. The export tax multiplier is normally negative and quite high, i.e., the removal--through taxation--of some of the income increase in the export sector reduces domestic demand and inflation.

A Method to Reduce the Linearization Error

Let Y and X be vectors of endogenous and exogenous variables in absolute levels, so that $f(Y, X) = 0$ represents the system of equations that are nonlinear in Y and X. Formulating all variables in relative change (y, x) permits linearization up to a vector of residual terms:

$$(1) \quad B\,y = A\,x + r(y, x)$$

where r is the residual term including all multiplicative effects, which are negligible for very small x; and B and A denote coefficient matrices of endogenous and exogenous variables containing base-year shares and parameter values. We assume adjustment takes place in one period, so that the coefficient matrices do not change; as a result this method does not address any error that is due to a nondynamic presentation.

The procedure is to iteratively approximate the residual term by evaluating the multiplicative term r at the values found for y in the previous iteration.

Step 0: Solve system (1) for $r^0=0$:

$$(2) \quad y^0 = B^{-1}\,A\,x$$

Step 1: Evaluate $r^1(y, x)$ for y^0 and solve system (1)

$$(3) \quad r^1 = r(y^0, x)$$

$$(4) \quad y^1 = B^{-1}\,A\,x + B^{-1}\,r(y^0, x) = B^{-1}\,[A \mid r^1] \begin{bmatrix} x \\ 1 \end{bmatrix}$$

This amounts to including a constant term in the exogenous variables x and augmenting the matrix A by a column r^1, i.e., $[A \mid r^1]$ in equation (4).

The correction in equation (4) is, for any endogenous variable y_i, calculated as the difference between the linear solution y_i^o and the nonlinear expression for $\bar{y}_i^o$ (denoted with a bar) from equation (1):

$$(3') \qquad r_i^1 = \bar{y}_i^o - y_i^o$$

where: $y_i^o = \sum_j B_{ij}^{-1} \sum_k A_{jk} x_k$ solution of step 0

$\bar{y}_i^o = f(y_{j \neq i}^o , x)$ nonlinear equation evaluated for the solution of step 0.

The error term r_i^1 is included as a constant in the equation for the i^{th} endogenous variable in the next round:

$$(4') \qquad y_i^1 = - \sum_{j \neq i} B_{ij} y_j^1 + \sum_k A_{ik} x_k + r_i^1$$

Step 2

$$(5) \qquad r^2 = r^1 + (\bar{y}^1 - y^1)$$

$$(6) \qquad y^2 = B^{-1} A x + B^{-1} r^2$$

where equation (5) adds the calculated difference of the next step to the error term.

The two following examples illustrate that determining the error term, r_i^o, involves calculating either a multiplicative term or the difference between the original nonlinear expression and the linearized form.

Equation (5c) for the nominal wage on page 6 is written in relative changes:

$$(5c) \qquad W = RW\ CPI$$

$$(5c'') \qquad w = \frac{\Delta W}{W^\circ} = \frac{RW^\circ\ CPI^\circ\ [(1 + rw)(1 + cpi) - 1]}{RW^\circ\ CPI^\circ}$$

$$w = (1 + rw)(1 + cpi) - 1 = rw + cpi + rw\ cpi$$

$$(5c') \qquad w = rw + cpi$$

The error in going from (5c") to the linearized form (5c'), i.e., rw cpi, can be quite large; for example, for rw=-25 percent, cpi=60 percent, the correct nominal wage in (5c") is 20 percent whereas (5c') gives 35 percent.

As a second example, consider equation (5d) for the CPI on page 6, written in relative change:

$$(5d) \qquad CPI = PD^{\theta}\ PM^{1-\theta}$$

$$(5d'') \qquad cpi = \frac{\Delta CPI}{CPI^\circ} = \frac{(PD^{\circ\theta}\ PM^{\circ 1-\theta})\ \{(1 + pd)^{\theta}(1 + pm)^{1-\theta} - 1\}}{(PD^{\circ\theta}\ PM^{\circ 1-\theta})}$$

$$(5d') \qquad cpi = \theta\ pd + (1 - \theta)\ pm$$

The error in going from the correct relative change in (5d") to the linearized form (5d') is calculated as:

$$r = (1 + pd)^{\theta}\ (1 + pm)^{1-\theta} - 1 - \theta\ pd - (1 - \theta)\ pm$$

For example, with θ=0.7, pd=40 percent, and pm=100 percent, the error is r=-2.2 percent.

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