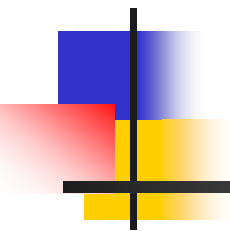


Building an Applied General Equilibrium Model



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Foreword

- 'A "logical picture" differs from an ordinary picture in that it need not look the least bit like its object. Its relation to the object is not that of a copy, but of analogy.
- ...The great value of analogy is that by it, and by it alone, we are led to seeing a single "logical form" in things which may be entirely discrepant as to content.'

Langer (1967)



Introduction

- Relevance

- Shocks and policies may have at once macroeconomic, structural, and distributional implications working through a number of flow-of-funds variables, and individual good and factor markets.
- This creates interdependence between stabilization, structural and distributional issues and a need for an analytical framework that accounts for this interdependence.
- A general equilibrium analysis offers such framework



Introduction

- Focus of presentation
 - Modeling an Open Market Economy
- Outline
 - The Logic of General Equilibrium Modeling
 - Working Definition
 - The Basic Walrasian Framework
 - Diagrammatic Representation
 - Circular Flow of Economic Activity
 - Social Accounting Matrix



Introduction

- Numerical Implementation in EViews
 - Specification
 - Closure
 - Calibration
 - Validation
 - Simulations
 - Dutch Disease
 - Deterioration of TOT



What is a General Equilibrium Model?

- A logical representation of a socioeconomic system wherein the behavior of all participants is compatible.
- Key modeling issues:
 - Identification of **participants**.
 - Specification of individual **behavior**.
 - Specification of mode of **interaction**.
 - Characterization and desirability of **compatibility**.



Basic Walrasian Framework

- Template for most applied CGE models.
- Two categories of agents or **participants**:
 - producers or firms
 - and consumers or households.



Basic Walrasian Framework

- **Optimizing behavior**
 - Entails specification of (1) **actions** an economic unit can take; (2) the **constraints** it faces; and (3) the **objective** function used to evaluate individual actions (Varian 1984).
 - **Supply** and **demand** behavior is thus an observable consequence of the optimization assumption.



Basic Walrasian Framework

- **Market interaction**: method of social coordination by mutual adjustment among participants based on "**quid pro quo**" (Lindblom 2001).
- **Compatibility**
 - All markets are in **equilibrium**: incentive configuration is such that effective demand equals supply.
 - Alternatively: No feasible change in individual behavior is worthwhile, or if a change is worthwhile, it must not be feasible.



Basic Walrasian Framework

- **Comparative Statics** entails comparison of equilibrium states associated with changes in the socioeconomic environment.
- Social **desirability** of any state depends on chosen criterion.
 - Criterion may involve both underlying social arrangements and outcomes from participation in such arrangements.



Basic Walrasian Framework

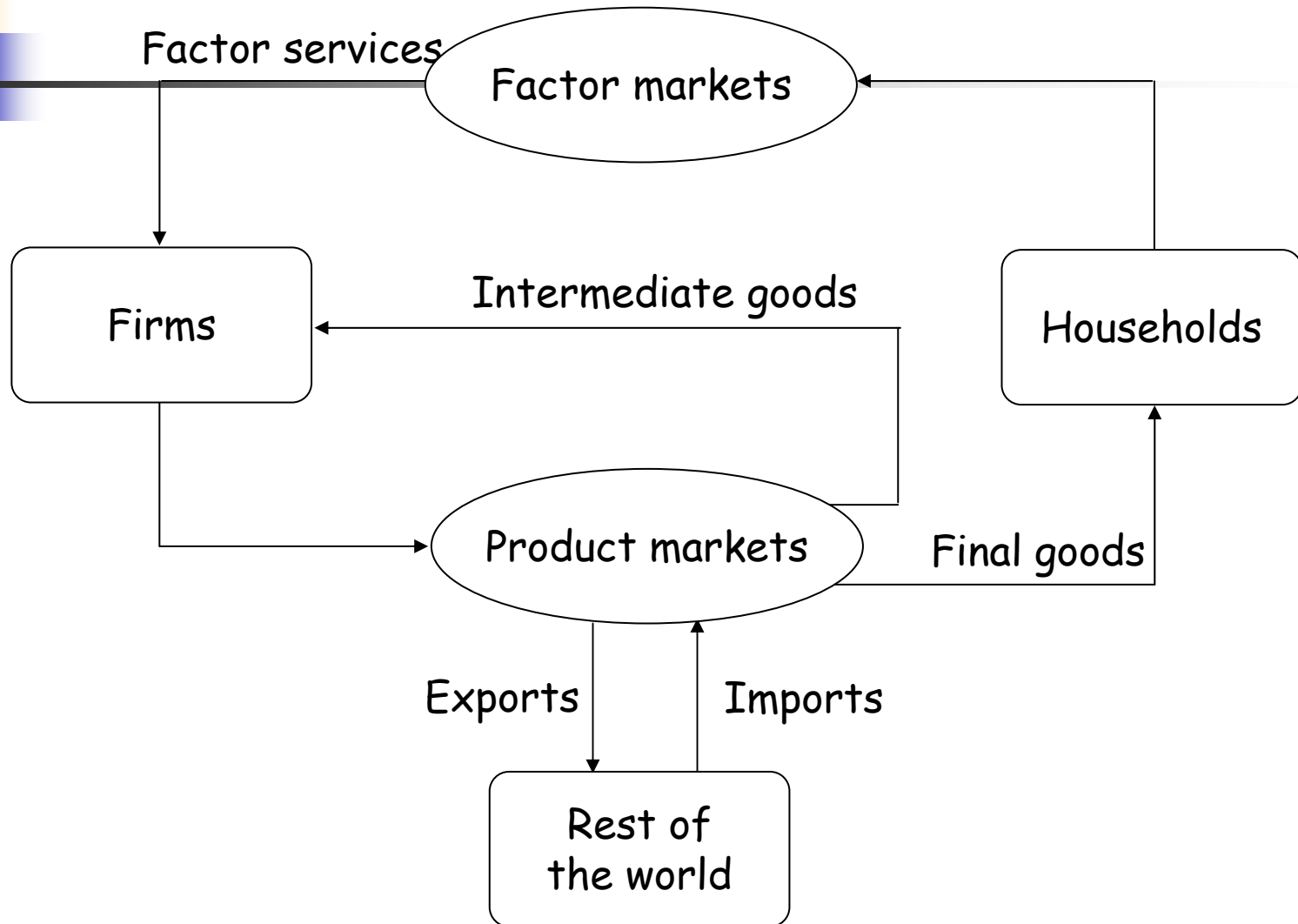
- A desirable social arrangement is a mechanism designed to control and coordinate the behavior of participants in a way that minimizes conflict and promotes cooperation understood as exchange of help (Lindblom 2001)
- **Social peace** would therefore be maintained if the market system is accepted (by law and popular acquiescence) as the preferred allocation mechanism.



Basic Walrasian Framework

- Pareto **efficiency** focuses on how well the system promotes individual objectives. Compatibility implies no other situation (in terms of outcomes) is unanimously preferred by all participants.
- **poverty/equity**-focused criterion: less poverty/inequality is preferred to more.

Circular Flow Chart of Economic Activity





Social Accounting Matrix

Structure of a Basic SAM for an Open Economy

	Activity	Commodity	Factor	Household	World	Total
Activity		Domestic Sales			Exports	Total Sales
Commodity	Intermediate Demand			Household Consumption		Total Demand
Factor	Factor Payments					Factor Payments
Household			Factor Payments		Balance of Trade	Total Household Income
World		Imports				Imports
Total	Total Cost	Total Supply	Factor Payments	Total Household Expenditure	Foreign Exchange	



Social Accounting Matrix

- An accounting framework that reflects the circular flow of economic activity.
- A square matrix, the dimension of which is determined by the number of sectors, agents and institutions considered.
- Each entry represents a payment to a row-account by a column-account.
- Consistency implies that row total must equal corresponding column total.
- Also, if all but one accounts balance, the last one must balance as well (Walras' law).



Social Accounting Matrix

Analytical Expression for a Basic SAM

	Activity	Commodity	Factor	Household	World	Total
Activity		$P_d X_d$			$P_e X_e$	$P_x X_s$
Commodity	$P_q Q_n$			$P_q Q_f$		$P_q Q_n + P_q Q_f$
Factor	WF_d					WF_d
Household			WF_s		RS_f	$WF_s + RS_f$
World		$P_m Q_m$				$P_m Q_m$
Total	$P_x X_s$	$P_q Q_s$	WF_s	$P_q Q_f$	$P_e X_e + RS_f$	



Numerical Implementation

- Specification
 - Simple Salter-Swan one-sector model with symmetric product differentiation for both imports and exports.
 - Domestic and foreign goods are imperfect substitutes.
 - A foundation for the study of the impact of macroeconomic imbalances and adjustment policies on the real sector of a small open economy (Devarajan, Lewis and Robinson 1990).
 - Three **agents**: producer, consumer and rest of the world.
 - Production sector sells output both domestically and on the world market.



Specification

- **Producer maximizes profit** subject to technical constraints and market opportunities at home and abroad.
- Consumption good is made up of domestic good and imports.
- **Consumer** owns all factors of production and **maximizes utility** subject to a budget constraint (or minimizes expenditures needed to achieve given level of utility) .



Specification

- Goods and factor **markets** are perfectly competitive, and full employment prevails.
- **Small country assumption**: country cannot affect the terms at which it is trading with the rest of the world.
- Assumption of full employment of all primary factors of production allows use of the production possibility frontier modeled as a constant elasticity of transformation function (CET).

$$X_s = A_x \left[\gamma_e X_e^{-\phi} + \gamma_d X_d^{-\phi} \right]^{\frac{1}{\phi}}$$



Specification

- Optimal behavior of producer represented by CET revenue function:

$$R(P_e, P_d; X_s) = \left(\frac{X_s}{A_x} \right) \left[\gamma_e^\omega P_e^{(1-\omega)} + \gamma_d^\omega P_d^{(1-\omega)} \right]^{\frac{1}{(1-\omega)}}$$

- where $\omega = 1/(1 + \varphi)$ stands for the elasticity of transformation.
- Supply of exports and that of domestic sales are derived from this revenue function by application of the Envelope theorem.



Specification

- Envelope Theorem

- Optimization assumption implies that the maximum value attainable by the objective function can be expressed in terms of various parameters that enter both the objective function and the constraints. This expression is the maximum value function (Dixit 1990).
- According to the envelope theorem, the change in the objective function induced by a change in a parameter while the choice variable adjusts optimally is equal to the partial derivative of the maximum value function with respect to the parameter (Varian 1984).



Specification

- Export supply function is the partial derivative of the revenue function with respect to the domestic price of exports.

$$X_e = (X_s / A_x) \left(\frac{\gamma_e}{P_e} \right)^\omega \left(\gamma_e^\omega P_e^{1-\omega} + \gamma_d^\omega P_d^{1-\omega} \right)^{\frac{\omega}{1-\omega}}$$

- Similarly for domestic sales

$$X_d = (X_s / A_x) \left(\frac{\gamma_d}{P_d} \right)^\omega \left(\gamma_e^\omega P_e^{1-\omega} + \gamma_d^\omega P_d^{1-\omega} \right)^{\frac{\omega}{1-\omega}}$$



Specification

- Domestic price of export

$$P_e = R\pi_e$$

- GDP deflator

$$P_x X_s = (P_e X_e + P_d X_d)$$

- The consumer is assumed to minimize the cost of a composite consumption good defined as a constant elasticity of substitution (CES) aggregate of imports and domestic goods (Armington aggregation).

$$Q_s = B_q \left[\beta_m Q_m^{-\rho} + \beta_d D_x^{-\rho} \right]^{\frac{1}{\rho}}$$



Specification

- The corresponding optimal level of expenditure is:

$$E(P_m, P_d; Q_s) = B_q^{-1} \left[\beta_m^\sigma P_m^{1-\sigma} + \beta_d^\sigma P_d^{1-\sigma} \right]^{\frac{1}{1-\sigma}} Q_s$$

- The elasticity of substitution is:

$$\sigma = \frac{1}{1 + \rho}$$

- Demand for domestic good

$$D_x = (Q_s / B_q) \left(\frac{\beta_d}{P_d} \right)^\sigma \left(\beta_m^\sigma P_m^{1-\sigma} + \beta_d^\sigma P_d^{1-\sigma} \right)^{\frac{\sigma}{1-\sigma}}$$



Specification

- Demand for imports

$$Q_m = (Q_s / B_q) \left(\frac{\beta_m}{P_m} \right)^\sigma \left(\beta_m^\sigma P_m^{1-\sigma} + \beta_d^\sigma P_d^{1-\sigma} \right)^{\frac{\sigma}{(1-\sigma)}}$$

- Domestic price of imports

$$P_m = R \pi_m$$

- Total expenditure on the composite consumption good

$$P_q Q_s = (P_m Q_m + P_d D_x)$$

- Household income

$$Y_h = P_x X_s + R S_f$$



Specification

- Demand for composite consumption good (assuming no savings)

$$Q_d = \frac{Y_h}{P_q}$$

- Goods market equilibrium

$$X_d = D_x \quad Q_s = Q_d$$

- Balance of trade

$$\pi_m Q_m - \pi_e X_e = S_f$$



Closure

- EViews requires a one-to-one mapping between equations and endogenous variables.
- The process of determining which variables to make endogenous and which exogenous is known generally as closure.
- In the Walrasian framework, only relative prices matter. If we multiply the price of domestic good and the exchange rate by a constant, all nominal values will be multiplied by the same constant and real variables will remain unchanged. Hence the system is said to be homogeneous of degree zero.



Closure

- We can therefore choose a *numéraire* good and fix its price exogenously. We select the price of the composite good Q , and make it exogenous.
- **Full employment** assumption means real GDP can be made exogenous.
- The **small country** assumption implies that world prices are exogenous. Finally, we make the balance of trade exogenous as well.



Closure

- The model also respects **Walras' law**: if all economic agents satisfy their budget constraints and all, but one, markets are in equilibrium, then the last market must also be in equilibrium. Alternatively, if all markets are in equilibrium and all, but one, budget constraints are binding, then the last budget constraint is binding as well (Dinwiddy and Teal 1988).
- Hence, we can drop one equilibrium condition from the system and it will still solve. We drop the household budget constraint by assigning to it a dummy endogenous called WALRAS. This dummy must equal zero when the law is satisfied by a solution of the model.



Closure

The Core Model of an Open Economy in EViews

$$\begin{aligned} XQ &= ces * (betam * XM^{(-rho)} + betad * XD^{(-rho)})^{(-1 / rho)} \\ PE &= EXR * PWE \\ PM &= EXR * PWM \\ PX * XS &= (PE * XE + PD * XD) \\ PD * XD &= (PQ * XQ - PM * XM) \\ XE &= (XS / cet) * (gammae / PE)^{\omega} * (gammae^{\omega} * (PE)^{(1 - \omega)} + gammad^{\omega} * (PD)^{(1 - \omega)})^{\omega / (1 - \omega)} \\ XD &= (XS / cet) * (gammad / PD)^{\omega} * (gammae^{\omega} * (PE)^{(1 - \omega)} + gammad^{\omega} * (PD)^{(1 - \omega)})^{\omega / (1 - \omega)} \\ XM &= (XQ / ces) * (betam / PM)^{\sigma} * (betam^{\sigma} * (PM)^{(1 - \sigma)} + betad^{\sigma} * (PD)^{(1 - \sigma)})^{\sigma / (1 - \sigma)} \\ YHH &= PX * XS + EXR * BOT \\ \text{WALRAS} &+ PQ * XQ = YHH \\ EXR * PWM * XM &= PE * XE + EXR * BOT \end{aligned}$$



Calibration

- To make the model fully computable we resort to **calibration**. This process solves the relevant equations for values of the parameters that are consistent with base year data.
- For the parameters of the CET aggregation function:
 - Assume a value for ω and compute $\varphi = (1 - \omega) / \omega$
 - The share parameters add up to one $\gamma_e + \gamma_d = 1$



Calibration

- Share parameter

$$\gamma_e = \frac{\frac{P_e}{P_d} \left(\frac{X_e}{X_d} \right)^{\frac{1}{\omega}}}{1 + \frac{P_e}{P_d} \left(\frac{X_e}{X_d} \right)^{\frac{1}{\omega}}} = \frac{1}{1 + \frac{P_d}{P_e} \left(\frac{X_e}{X_d} \right)^{-\frac{1}{\omega}}}$$

- The shift parameter of the CET is computed as:

$$A_x = \frac{X_s}{\left[\gamma_e X_e^{-\phi} + \gamma_d X_d^{-\phi} \right]^{\frac{1}{\phi}}}$$



Calibration

- Calibration of the parameters of the Armington aggregation is entirely analogous:

$$\rho = \frac{1 - \sigma}{\sigma}$$

$$\beta_m = \frac{1}{1 + \frac{P_d}{P_m} \left(\frac{Q_m}{D_x} \right)^{-\frac{1}{\sigma}}}$$

$$\beta_m + \beta_d = 1$$

$$B_q = \frac{Q_s}{\left[\beta_m Q_m^{-\rho} + \beta_d D_x^{-\rho} \right]^{\frac{1}{\rho}}}$$



Calibration

Baseline Data

	Activity	Commodity	Household	Rest of World	Total
Activity		75		25	100
Commodity			100		100
Household	100			0	100
Rest of World		25			25
Total	100	100	100	25	

Source: de Melo and Robinson (1989)



Calibration

Calibration of the Core Model of an Open Economy in EViews

```
MODEL CALIBER
omega.fill -0.2, -0.5, -2, -5, -500
sigma.fill 0.2, 0.5, 2, 5, 5
CALIBER.APPEND gammae=1/(1 + ( PD/PE)*(XE/XD)^(-1/omega) )
CALIBER.APPEND gammad=(1 - gammae)
CALIBER.APPEND phi=(1-omega)/omega 'Exponent in the CET function
CALIBER.APPEND cet=XS/( gammaE*XE^(-phi) + gammaD*XD^(-phi) )^(-1/phi)
CALIBER.APPEND betam=1/(1 + ( PD/PM)*(XM/XD)^(-1/sigma) )
CALIBER.APPEND betad=(1 - betaM)
CALIBER.APPEND rho=(1-sigma)/sigma 'Exponent in the CES Armington function
CALIBER.APPEND ces=XQ/( betaM*XM^(-rho) + betaD*XD^(-rho) )^(-1/rho)
CALIBER.SCENARIO ACTUALS
CALIBER.SOLVE(s=d, d=s,o=n)
CALIBER.MAKEGROUP(a) CALIGRP @ENDOG
FREEZE(CALIBRATED) CALIGRP
```



Calibration

Calibration Results for the Core Model of an Open Economy

obs	OMEGA	SIGMA	BETAD	BETAM	CES	CET	GAMMAD	GAMMAE	PHI	RHO
1	-0.200	0.200	0.996	0.004	1.431	3.177	0.004	0.996	-6.00	4.00
2	-0.500	0.500	0.900	0.100	1.600	2.610	0.100	0.900	-3.00	1.00
3	-2.000	2.000	0.634	0.366	1.866	2.151	0.366	0.634	-1.50	-0.50
4	-5.000	5.000	0.555	0.445	1.944	2.059	0.445	0.555	-1.20	-0.80
5	-500.00	5.000	0.555	0.445	1.944	2.001	0.499	0.501	-1.002	-0.80

Source: Author's calculations



Validation

- A series of tests to ensure that the calibrated model behaves according to the underlying structure
 - **Check calibration**
 - Single equation solution (no interaction) to isolate possibly offending equation.
 - Simultaneous solution to check coherence (make sure model reproduce baseline).



Validation

- Within the Walrasian Framework:
 - **Check Walras' law**: dropped equation must be satisfied by solution (if using dummy to exclude equation, solved dummy must equal zero or be very close to zero).
 - **Homogeneity test**: the assumptions of optimization and interaction within competitive markets imply that the model is homogenous of degree zero. Multiplying the *numéraire* price by a constant k produces a solution where real values remain unchanged but all nominal values are multiplied by k .



Validation

- Homogeneity test: Multiply numéraire price by 2.

Omega	Sigma	EXR	PD	PE	PM	PX	Walras	YHH	XD	XE	XM	XQ
-0.2	0.2	2.0	2.0	2.0	2.0	2.0	0.0	200.0	75.0	25.0	25.0	100.0
-0.5	0.5	2.0	2.0	2.0	2.0	2.0	0.0	200.0	75.0	25.0	25.0	100.0
-2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	200.0	75.0	25.0	25.0	100.0
-5.0	5.0	2.0	2.0	2.0	2.0	2.0	0.0	200.0	75.0	25.0	25.0	100.0
-500.0	5.0	2.0	2.0	2.0	2.0	2.0	0.0	200.0	75.0	25.0	25.0	100.0

Source: Author's calculations



Implications of Dutch Disease

- Dutch Disease

- Refers to decline of the Netherlands' export competitiveness in the 1970s following discovery and exploitation of the Groningen natural gas fields (Benjamin, Devarajan and Weiner 1989).
- In general, the adverse effect that real exchange appreciation has on some tradable sectors of the economy as a result of an increase in foreign capital inflow.
- Use above model to simulate implications of an increase of the balance of trade from 0 to 10. 40



Dutch Disease

- Structural and Welfare Implications

Omega	Sigma	EXR	PD	PX	RPD	RPX	XD	XE	XM	XQ
-0.2	0.2	0.46	1.20	1.02	0.38	0.45	77.39	21.28	31.28	106.97
-0.5	0.5	0.75	1.09	1.01	0.68	0.74	77.95	21.46	31.46	108.66
-2.0	2.0	0.93	1.02	1.00	0.91	0.93	78.28	21.57	31.57	109.65
-5.0	5.0	0.97	1.01	1.00	0.96	0.97	78.35	21.59	31.59	109.86
-500.0	5.0	1.00	1.00	1.00	1.00	1.00	82.41	17.59	27.59	110.00

Source: Author's calculations



Dutch Disease

- Contraction of tradable sector relative to non-tradable induced by an increase in domestic prices relative to world prices (real appreciation of the exchange rate, Devarajan et al. 1990).
- On the demand side:
 - The foreign transfer goes entirely to the consumer (by assumption) hence consumption and welfare (XQ) increase (see above table).



Dutch Disease

- Demand side
 - In the limit, increase in welfare equals the amount of the transfer.
 - There is an increase in the consumption of both domestic good (XD) and imports (XM) leading to an increase in the price of the domestic good (PD) relative to price of tradable. Hence real appreciation (EXR/PD ranges from 0.38 to 1).



Dutch Disease

- Supply side
 - Real appreciation shifts incentives in favor of the domestic sector against exports. Resources move accordingly. More of the domestic good is produced. Export sector declines.
 - Role of structural parameters
 - The higher the elasticity of transformation, the closer the increase in welfare equal the amount of the transfer.



Dutch Disease

- Role of structural parameters
 - The magnitude of the elasticity of substitution underpins the extent of real appreciation (Devarajan et al. 1990):
 - (1) If zero, imports and domestic goods are perfect complements. More of both goods are consumed, and an increase in price of the domestic good leads to real appreciation.
 - (2) If infinity, both goods are perfect substitutes. The demand for the domestic good will not change and therefore there will be no real appreciation and no Dutch disease.



Dutch Disease

- Should it be a matter of policy concern?
 - If underlying real appreciation is sudden or reversible, then policymakers may wish to mitigate its impact on tradable sectors (Corden 2002).
 - If fixed exchange rate with independent monetary policy (or in the regime of managed float) the government may try to sterilize the effects of foreign capital inflows on the money supply. Fiscal contraction can also help.



Dutch Disease

- Case of Cameroon during the oil boom of the 1970s:
- (Benjamin, Devarajan and Weiner 1989):
 - Fixed exchange rate and no independent monetary policy.
 - Saved a large share of oil revenue abroad and use part of windfall to increase producer price of cash crop thus counteracting the adverse incentive effects induced by real appreciation.



A Deterioration of the Terms of Trade

- Structural and Welfare Implications

Omega	Sigma	EXR	PD	PX	RPD	RPX	XD	XE	XM	XQ
-0.2	0.2	1.12	0.93	0.97	1.21	1.15	74.23	25.70	23.37	97.44
-0.5	0.5	1.01	0.96	0.98	1.05	1.04	74.54	25.45	23.13	97.58
-2.0	2.0	0.96	0.98	0.98	0.98	0.98	75.87	21.58	21.92	97.71
-5.0	5.0	0.95	0.99	0.98	0.96	0.97	78.35	21.58	19.62	97.84
-500.0	5.0	0.98	0.98	0.98	1.00	1.00	81.40	18.60	16.91	97.95

Source: Author's calculations



A Deterioration of the Terms of Trade

- A 10% increase in the world price of imports
 - There is a decrease in welfare associated with this deterioration of the terms of Trade (XQ is uniformly lower than its base value).
 - As expected, structural impact hinges on chosen **elasticities**.
 - Two cases:
 - σ less than one
 - σ greater than one

A Deterioration of the Terms of Trade



- **Case 1: Domestic goods and imports are complements**
 - Less consumption of both domestic good and imports.
 - A fall in the price of domestic goods leads to a real depreciation of the exchange rate which attracts resources in the export sector. Increase in the production of exports to pay for more expensive imports.



A Deterioration of the Terms of Trade

- **Case 2: Domestic goods and imports are substitutes**
 - There is an increase in the consumption of the home good with less consumption of imports.
 - There is an appreciation of the real exchange rate as the price of the domestic good increases relative to that of foreign goods.
 - Real appreciation shifts resources away from export sector to home goods.



A Deterioration of the Terms of Trade

- What drives the outcome?
 - **Income and substitution effects** associated with the increase in the world price of imports.
 - When $\sigma < 1$ (case 1), income effect dominates the substitution effect. There is real depreciation induced by fall in domestic price. Incentive configuration favors the export sector.
 - When $\sigma > 1$, substitution effect dominates income effect. Real appreciation leads to the expansion of the domestic sector and a contraction of the export sector.



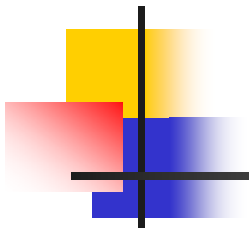
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The End.