Exchange Rates and CGE Models

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GTAP Conference

June 2003

Does a CGE Model Have a Meaningful Exchange Rate?

- No
  - Whalley and Yeung: a “parameter”
  - Gunning and Keyzer: an “indicator” or “normalization” reflecting choice of numeraire
    - They refer to models with two numeraires
  - Srinivasan
  - GTAP (???)

Does a CGE Model Have a Meaningful Exchange Rate?

- Yes: single-country models
  - World Bank structural adjustment models
    - Dervis, de Melo, and Robinson
    - Tarr and associates
    - Devarajan, Lewis, and Robinson
      - 1-2-3 model and others
    - Branson, Bourguignon, and de Melo
    - Agenor: macro-CGE models
  - IFPRI standard model
  - Orani-type models

Does a CGE Model Have a Meaningful Exchange Rate?

- Yes: world models
  - World Bank world models
    - van der Mensbrugghe
  - OECD world models
    - Walras and descendents
    - Development Centre models
  - Michigan world model
  - McKibbin-Sachs-Wilcoxen models
  - IFPRI world models

If Yes, What Is It?

- A “real” variable?
- A price signal to agents?
- A “macro” variable?
- A “financial” variable?
- Does it correspond to “observed” exchange rates in data?

References

- J.W. Gunning and M.A. Keyzer (1995), “Applied General Equilibrium Models for Policy Analysis.” In J. Behrman and T.N. Srinivasan, *Handbook of Development Economics, Vol. III.*
- V. Ginsburgh and J. Waelbroeck (1981), *Activity Analysis and General Equilibrium Modeling.*

References

- V. Ginsburgh and M. Keyzer, *The Structure of Applied General Equilibrium Models.*
- V. Ginsburgh and S. Robinson (1984), "Equilibrium and Prices in Multisector Models." In M. Syrquin, L. Taylor, and L.E. Westphal (eds.), *Economic Structure and Performance*.

Elements of a CGE Model

- Actors: consumers and producers
- Motivation: utility maximization and profit maximization
- Institutional structure
  - Competitive markets
- Signals: prices and wages

Elements of a CGE Model

- Constraints on actors
  - Technology
  - Endowments (budget constraints)
- System constraints
  - Factor supplies
- Equilibrium conditions
  - Supply-demand balance on all markets

Important Distinctions

- Equilibrium conditions
- Equilibrating variables
- Equilibrating mechanisms

Negishi Formulation

$$\text{Max} \sum_k \alpha_k U_k(Q^k) \quad \text{k "actors"}$$

$$\sum_k Q_i^k \le f_i(F_{i,f}^D) \qquad \text{technology} \qquad \pi_i^Q$$

$$\sum_i F_{i,f}^D \le \sum_k \overline{F}_f^k \qquad \text{system constraints} \quad \pi_f^F$$

find α's such that π's act as equilibrium prices

Ginsburgh-Waelbroeck: Master Program

Add agent budget constraints:

$$Y_k = \sum_f W_f \bar{F}_f^k = \sum_i P_i Q_i^k$$

Find α_k such that: $W_f = \pi_f^F$

and $\mathrm{P_i} = \pi_i^Q$

CGE Formulation

Excess demand equations:

$$e_i^Q(P,W) = 0$$

$$e_f^F(P,W) = 0$$

CGE With Macro Constraints

$$e_i^Q(P,W,\mu)=0$$

$$e_f^F(P,W,\mu)=0$$

$$\psi_m(P,W,Q,F,\mu)=0$$

m macro constraints

μ_m macro equilibrating variables

CGE Equilibrium

- "Flow" equilibrium in factor and product markets
- "Flow" macro equilibrium: "Closure"
  - $S = I$
  - $G = T + S^G$
  - $M = E + S^F$
- Define macro equilibrating variables

Other Equilibrium Concepts

- Asset market equilibrium
  - Portfolio behavior
  - “Financial” variables: “claims” on future delivery of goods or “title” to assets
  - Time enters the model
- Dynamic equilibrium
  - Recursive
  - “Forward looking” agents
  - Rational expectations

Trade-Focused CGE Models

- Add exports and imports to closed-economy model
- Add a new agent: “rest of world”
  - Budget constraint: trade balance
- New equilibrating variable: “parameter”
- Nature of traded and non-traded goods
  - Non-traded factors and commodities
  - “Tradable” commodities

Armington Insight

- Specify traded goods as imperfect substitutes for domestic goods with the same sector classification.
- Allow degrees of “tradability” rather than dichotomous classification.
- Armington approach provides a good theoretical and empirical framework for analyzing trade policy.

1-2-3 Model

- 1 country, 2 activities, 3 commodities
- 2 activities, producing D and E
  - E not consumed domestically
- Additional commodity, M, consumed domestically but not produced
- Generalization of the Salter-Swan model

1-2-3 Model

- Aggregate GDP (X) is fixed.
  - Full employment model.
- Trade balance set exogenously.
- World prices of M and E are fixed.
- Total absorption (Q) is endogenous.

Basic 1-2-3 CGE Model

Flows

1. $\bar{X} = G\left(E, D^S; \Omega\right)$

2. $Q^S = F\left(M, D^D; \sigma\right)$

3. $Q^D = \dfrac{Y}{P^q}$

4. $\dfrac{E}{D^S} = g_2\left(P^e, P^d\right)$

5. $\dfrac{M}{D^D} = f_2\left(P^m, P^d\right)$

6. $Y = P^x \bar{X} + R B$

Prices

7. $P^m = R \pi^m$

8. $P^e = R \pi^e$

9. $P^x = g_1\left(P^e, P^d\right)$

10. $P^q = f_1\left(P^m, P^d\right)$

11. $R \equiv 1$

Equilibrium Conditions

12. $D^D - D^S = 0$

13. $Q^D - Q^S = 0$

14. $\pi^m M - \pi^e E = B$

Basic 1-2-3 CGE Model

Identities

15. $P^x \Box X \equiv P^e \Box E + P^d \Box D^S$

16. $P^q \Box Q^S \equiv P^m \Box M + P^d \Box D^D$

17. $Y \equiv P^q \Box Q^D$

Basic 1-2-3 CGE Model

Endogenous Variables

E: Export good

M: Import good

D^S: Supply of domestic good

D^D: Demand for domestic good

Q^S: Supply of composite good

Q^D: Demand for composite good

Y: Total income

P^e: Domestic price of export good

P^m: Domestic price of import good

P^d: Domestic price of domestic good

P^x: Price of aggregate output

P^q: Price of composite good

R: Exchange rate

Exogenous Variables

π^e: world price of export good

π^m: world price of import good

B: Balance of trade

σ: Import substitution elasticity

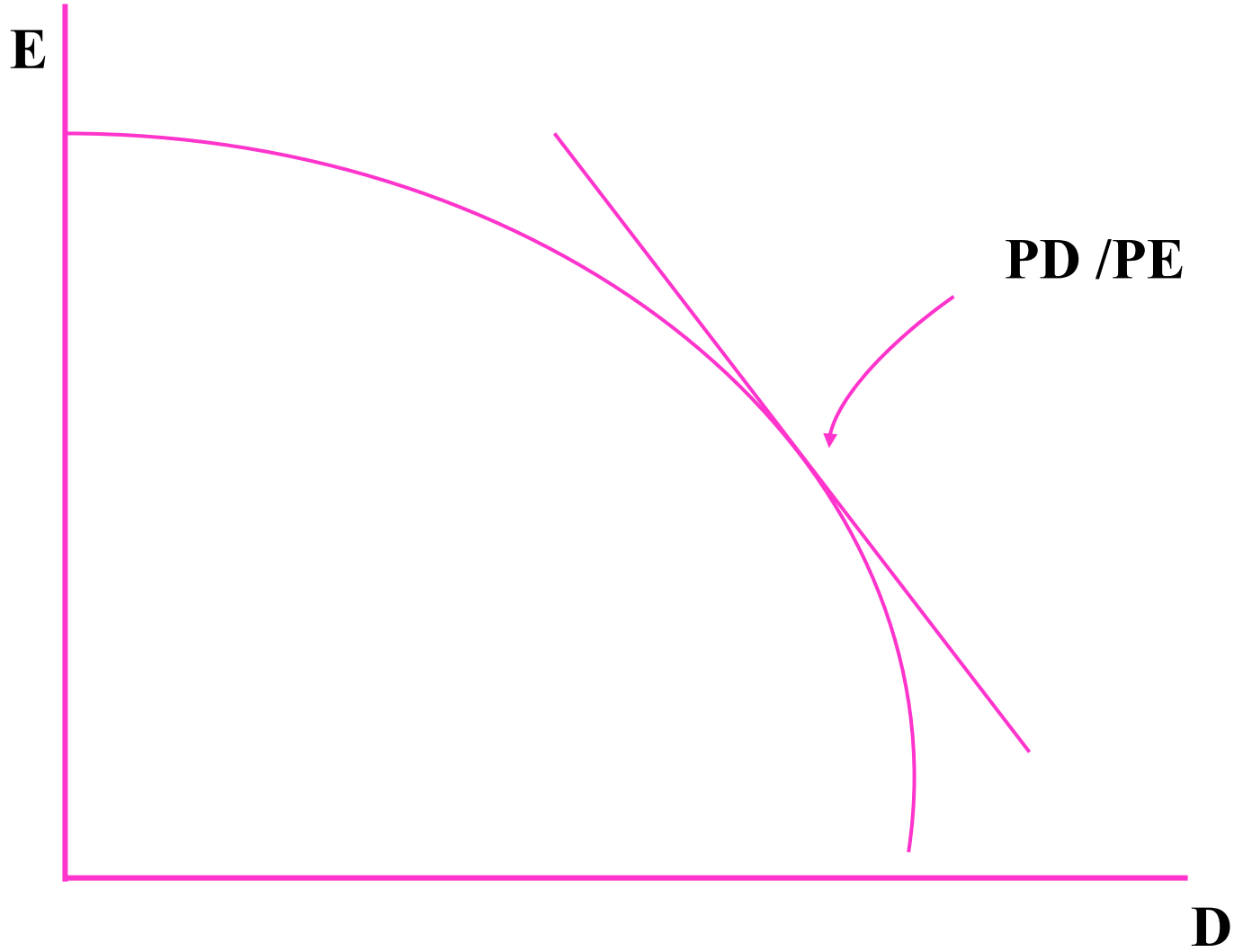
Ω: Export transformation elasticity

SAM for 1-2-3 Model

	Activities	Commod	Hshld	World
Activities		$P^d \square D^D$		$P^e \square E$
Commodities			$P^q \square Q^D$	
Households	$P^x \square \overline{X}$			$R \square B$
World		$P^m \square M$		
Total	$P^d \square D^S + P^e \square E$	$P^q \square Q^S$	Y	

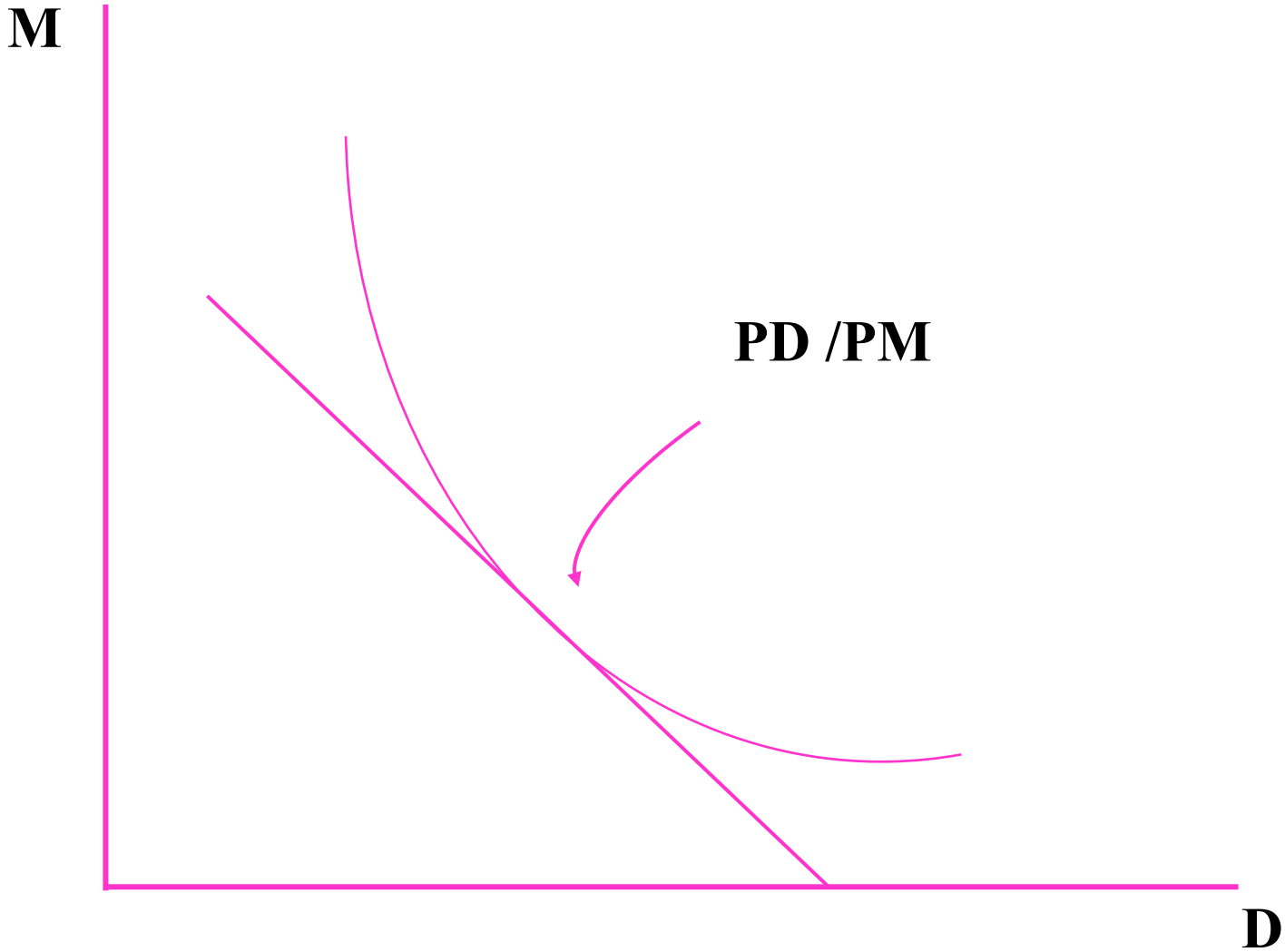
$$E/D = k\,(P_E / P_D)^{\Omega}$$

$$P_E = R \cdot pwe$$



$$M/D = k'(P_D / P_M)^{\sigma}$$

$$P_M = R \cdot \pi^m$$



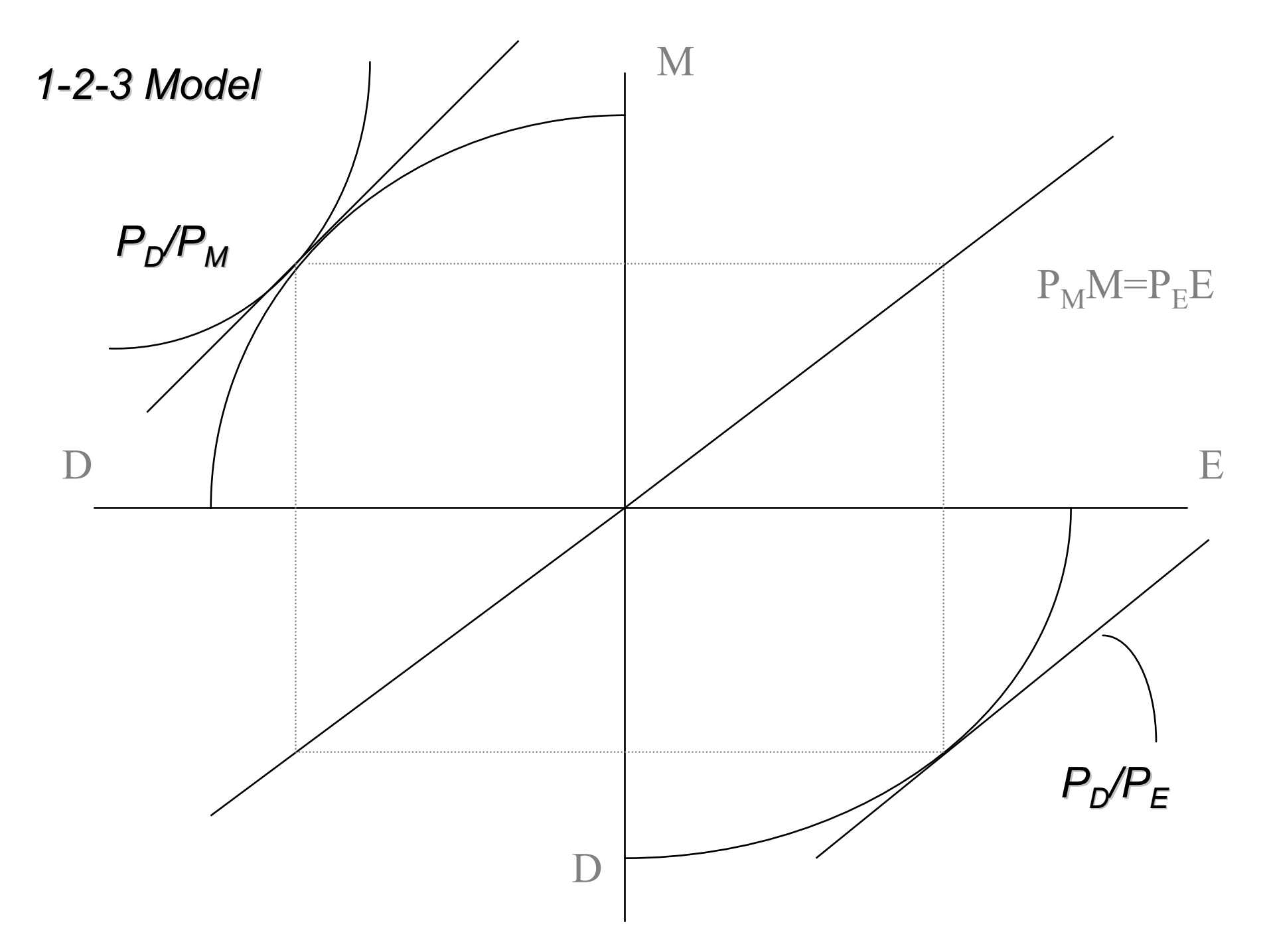
1-2-3 Programming Model

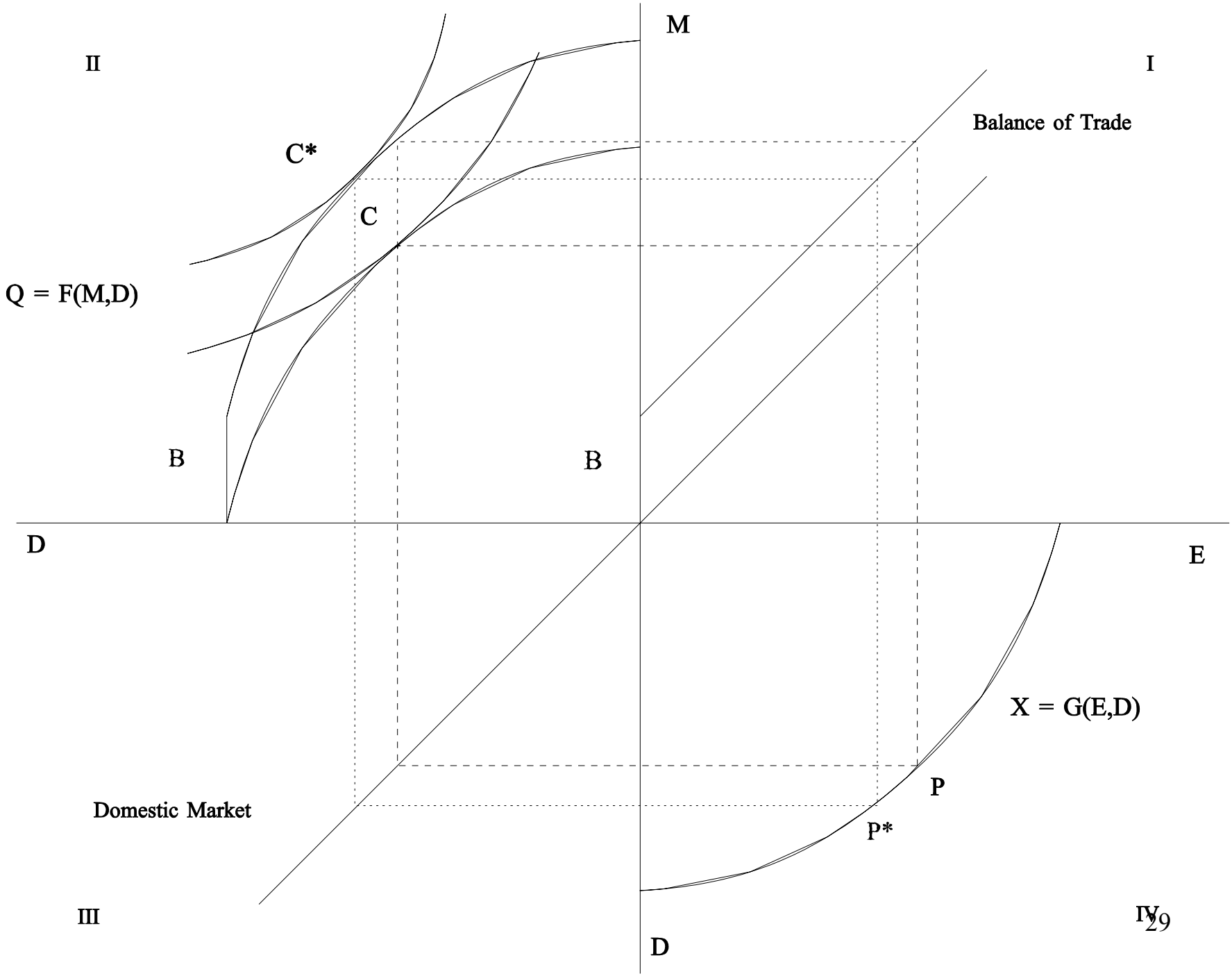
Maximize $Q = F\left(M, D; \sigma\right)$

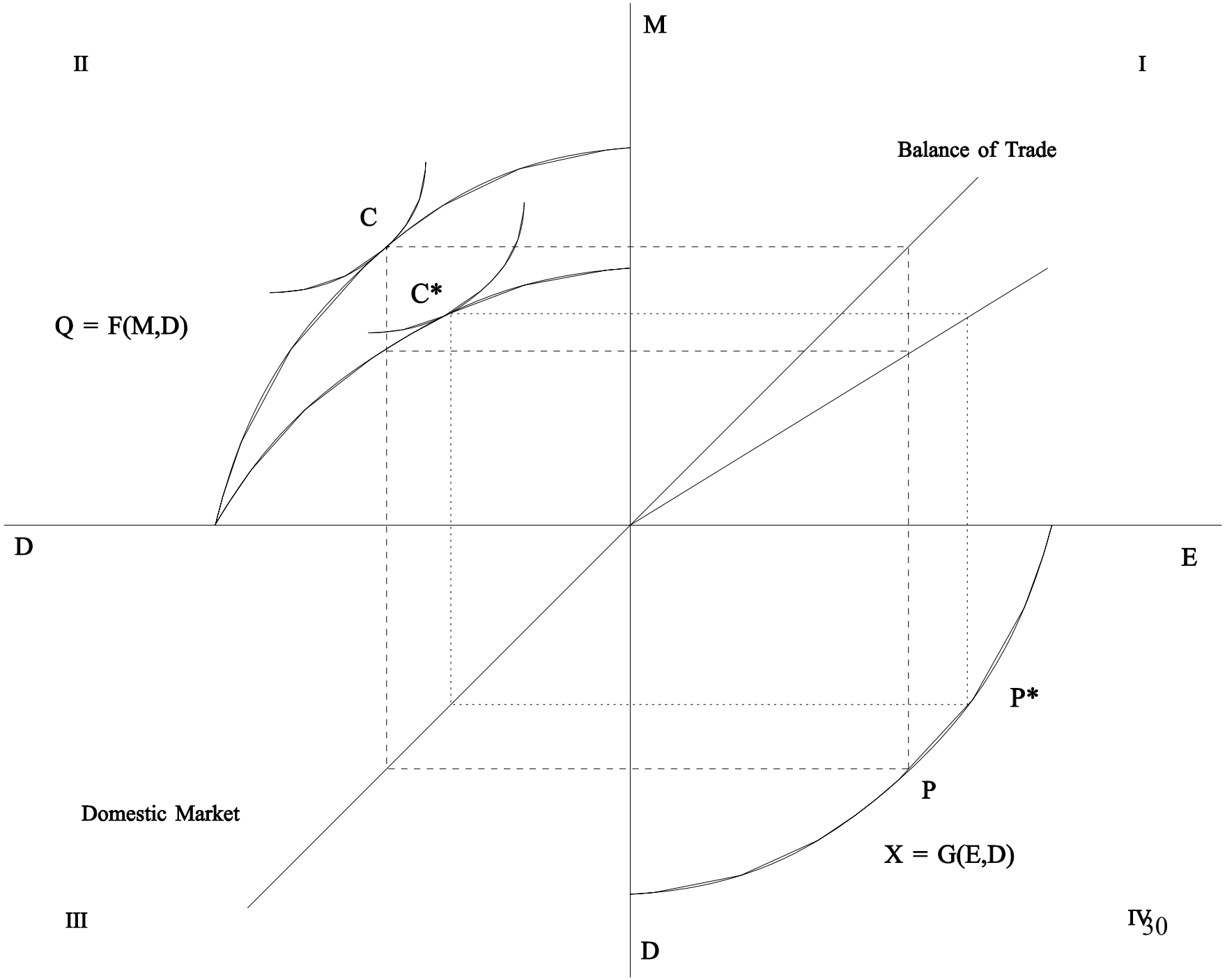
with respect to: M, E, D^D, D^S

subject to:

		Shadow Prices
1. $G\left(E, D^S; \Omega\right) \le \overline{X}$	technology	$\lambda^{\mathrm{x}} = P^x / P^q$
2. $\pi^m \cdot M \le \pi^e \cdot E + \overline{B}$	balance of trade	$\lambda^b = R / P^q$
3. $D^D \le D^S$	domestic market	$\lambda^d = P^d / P^q$


1-2-3 Model
M
P_D/P_M
$P_MM=P_EE$
D
E
D
P_D/P_E


M
II
I
Balance of Trade
C*
C
Q = F(M,D)
B
B
D
E
X = G(E,D)
P
P*
Domestic Market
III
IV
D


M
II
I
Balance of Trade
C
C*
Q = F(M,D)
D
E
P*
P
Domestic Market
X = G(E,D)
III
IV
D

Simple 1-2-3 Model

$$(1) \quad \overline{X} = G(D, E; \Omega)$$

$$(2) \quad Q = F(D, M; \sigma)$$

1-2-3 Model

$$(3) \quad \frac{E}{D} = k_2 \left(\frac{P^e}{P^d} \right)^{\Omega}$$

$$(4) \quad \frac{M}{D} = k_1 \left(\frac{P^d}{P^m} \right)^{\sigma}$$

1-2-3 Model

$$(5) \quad P^m = R \cdot \pi^m$$

$$(6) \quad P^e = R \cdot \pi^e$$

$$(7) \quad \pi^m \cdot M = \lambda \cdot \pi^e \cdot E$$

Variables and Parameters

- Variables
  - $E, M, D, Q, P^d, P^e, P^m, R$
- Parameters or exogenous variables

$$\pi^e,\ \pi^m, \lambda, \sigma, \Omega, \bar{X}$$

$$B = (\lambda - 1)\pi^e E \text{ so } B = 0 \Rightarrow \lambda = 1$$

- 8 variables, 7 equations
  - Choice of numeraire. Often R ≡ 1.

Real Exchange Rate Change

$$\hat{M} - \hat{D} = \sigma\left(\hat{P}^d - \hat{P}^m\right)$$

$$\hat{E} - \hat{D} = \Omega\left(\hat{P}^e - \hat{P}^d\right)$$

$$\hat{\pi}^m + \hat{M} = \hat{\lambda} + \hat{\pi}^e + \hat{E}$$

$$\hat{P}^e = \hat{R} + \hat{\pi}^e$$

$$\hat{P}^m = \hat{R} + \hat{\pi}^m$$

Equilibrium Domestic Price

$$\hat{P}^d = \frac{1}{(\sigma + \Omega)}\left[(\sigma - 1)\cdot\hat{\pi}^m + (1 + \Omega)\cdot\hat{\pi}^e + \hat{\lambda}\right]$$

$$R \equiv 1 \Rightarrow \hat{R} = 0$$

Equilibrium PLD EXR

$$\hat{R} - \hat{P}^d =$$ PLD exchange rate

$$-\frac{\left(\sigma \cdot \hat{\pi}^m + \Omega \hat{\pi}^e\right)}{\sigma + \Omega}$$ world inflation

$$+\frac{\left(\hat{\pi}^m - \hat{\pi}^e\right)}{\sigma + \Omega}$$ terms of trade

$$-\frac{\hat{\lambda}}{\sigma + \Omega}$$ trade balance

Choices of Numeraire

- R: exchange rate
- $P^{X:}$ GDP deflator
- $P^{Q:}$ consumer price index
- $P^{D:}$ price index of non-traded goods
- "Natural" choice would be R or P^D, given equilibrating mechanism
  - But results are the same for all choices

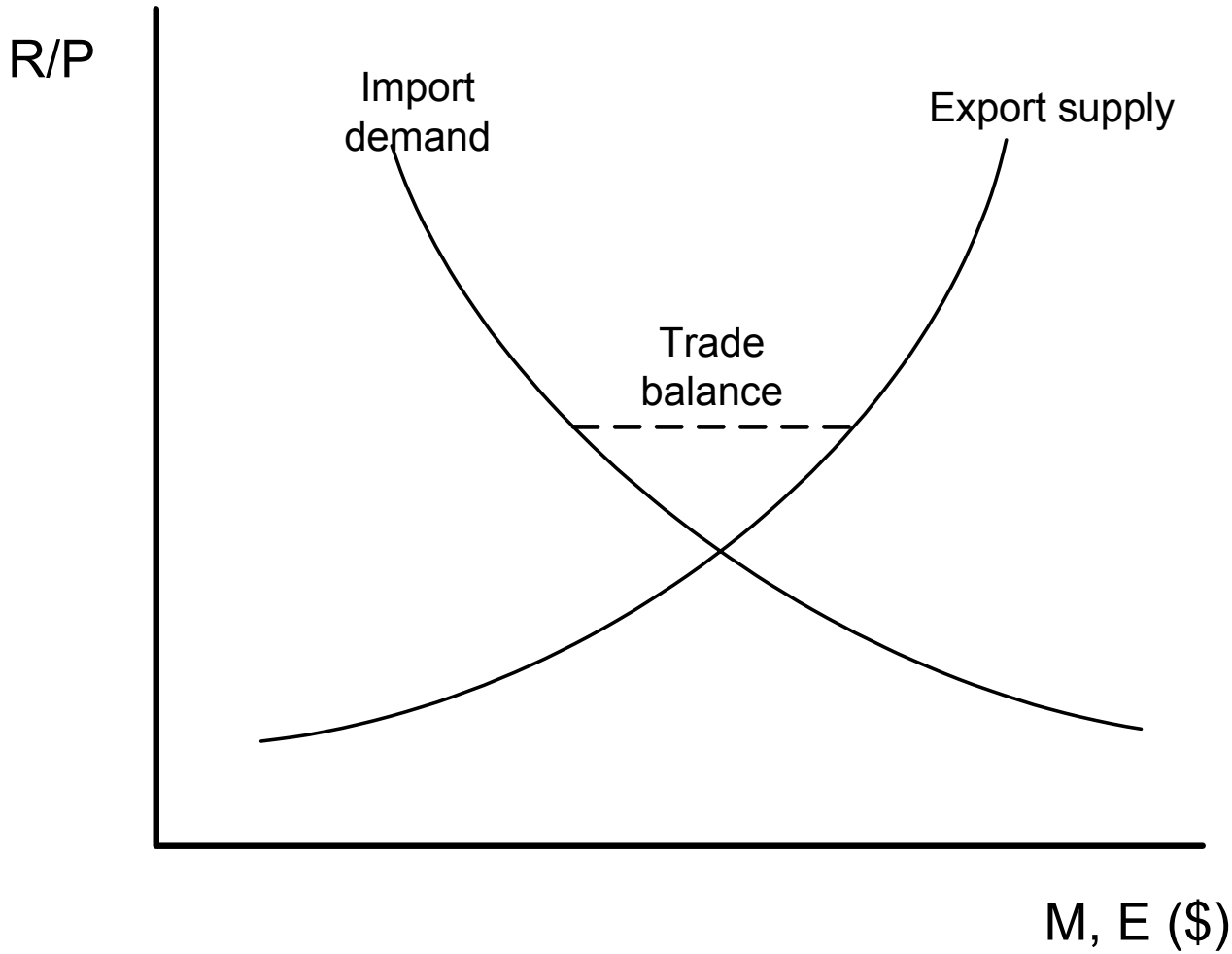
Macro Trade Relationships

- Constraint: balance of trade
- Equilibrium condition: trade balance equation
- Equilibrating variable: exchange rate
- Equilibrating mechanism: relative prices of traded to non-traded commodities
  - Variation in “real” exchange rate

Macro Trade Relationships

- Generate “general equilibrium” import demand and export supply curves
  - Vary the trade balance exogenously and solve for:
    - Equilibrium exchange rate and
    - Aggregate exports and imports
- “Macro” flow relationships

E, M, Supply-Demand



Trade Balance

- Units of trade balance: foreign currency
- Trade balance is a “claim” on foreign production; e.g., exports from rest of world
  - Odd notion, because there is no reason that any actor should want to hold such a claim in the CGE framework
  - Yet, must account for it in CGE model

Exchange Rate Variable

- Units of an exchange rate
- Standard macro relationships
  - Export supply and import demand curves
- Exchange rate equilibrating mechanism
  - Salter-Swan and 1-2-3 models
  - Standard relative price adjustment mechanism

Old Saying

- If it quacks like a duck,
- And it walks like a duck,
- And it looks like a duck,
- Then it must **be** a duck.

Macro Relationship

- Model specifies a monotonic relationship between the real exchange rate and the trade balance
  - Fix B, real exchange rate is endogenous
  - Fix real exchange rate, B is endogenous
- Three variables: R, B, and P
  - One variable, R or P, set by choice of numeraire
  - Can fix one other variable: B or either P or R.
  - Definition of real exchange rate variable is open

Other Macro Relationships

- R as a “signal” in financial markets
  - Equalization of interest rate minus inflation minus devaluation
  - Adjustment in asset markets affects trade balances, which are then endogenous
  - Time is inherently part of the analysis
- Different agents, different model, same variable
  - These financial models need to honor the relationship in commodity markets between R and the trade balance

Is R a “Macro” Variable?

- Yes
- Equilibrating variable defining a flow macro equilibrium in the trade balance
  - Trade balance “constraint”
  - Not “merely” the budget constraint of an “agent”.

Is R a “Financial” Variable?

- No.
- No financial assets in the model.
  - No money, domestic or foreign
  - Trade balance is odd: an implicit “claim” but no accounting of the stock of claims.
    - Similar to treatment of S=I in macro closure
- No intertemporal equilibrium concept

Is R a “signal” to Agents?

- No
- No agent sees R as a signal in his/her decision making
  - It is **not** the price of foreign exchange
- There is an implicit relationship between R and the trade balance
  - Works through the real exchange rate
  - Relative prices of traded to nontraded commodities

Is R “Observable” in data?

- Yes
- Can compute real exchange rate as defined, say, in the IMF *International Financial Statistics*
  - Either through choice of numeraire or by post-solution calculation
- R works exactly as it should in flow macro models
  - Can compute “equilibrium” R after a shock

“Cash in Advance” Model

- Money in utility or production functions
  - Credit requirements for production
- Money/credit in these models need not be treated as a “financial” variable
  - An “input” that provides a flow of services
  - Standard flow equilibrium
- Long CGE tradition
  - Taylor and others

Rest of World as an “Agent”

- In a single-country model, the rest of the world is treated as an agent with simple behavior
  - E.g., small-country assumption
  - Demand curves for some exports

Rest of World as an “Agent”

- Treatment is inconsistent with viewing the “agent” as “country” with its own CGE model
  - Whalley and Yeung
  - Gunning and Keyzer
- So what?
  - “Representative” country may be empirically a very bad specification
  - Agent approach supports econometric estimates
  - Must still honor trade balance constraint
    - No problem with Walras’ Law

Multi-Country Models

- "Rest of world" is now one or more countries rather than a single "agent"
- Numeraire issue
  - Country numeraires
  - Additional exchange rate numeraire
    - Reference country or composite
  - Units of trade balances
    - Numeraire "matters"

Trade Balances

- "Units" of trade balances matter
  - Must add up on global scale
  - "Claims" against what?
- Choices and numeraires
  - U.S. dollar: many models
  - OECD basket: van der Mensbrugghe
  - "Wage-rental" units: GTAP (?)
- Numeraire does not matter if you "deflate" trade balances explicitly in the world model

Conclusion

- Single and multi-country CGE models contain exchange rates
- The models are theoretically clean generalizations of the Salter-Swan model
- Exchange rates are “macro” variables that equilibrate trade balance constraints
  - No financial variables in the model
- They models define only flow equilibria, and macro equilibria must be defined in flow terms

Conclusions

- The treatment of exchange rates in CGE models is consistent with treatment in many macro models
  - CGE models are commonly being used as the “supply side” in macro models
- Extensions to assets, asset markets, and dynamics is challenging