Are Shocks to the Terms of Trade Shocks to Productivity?

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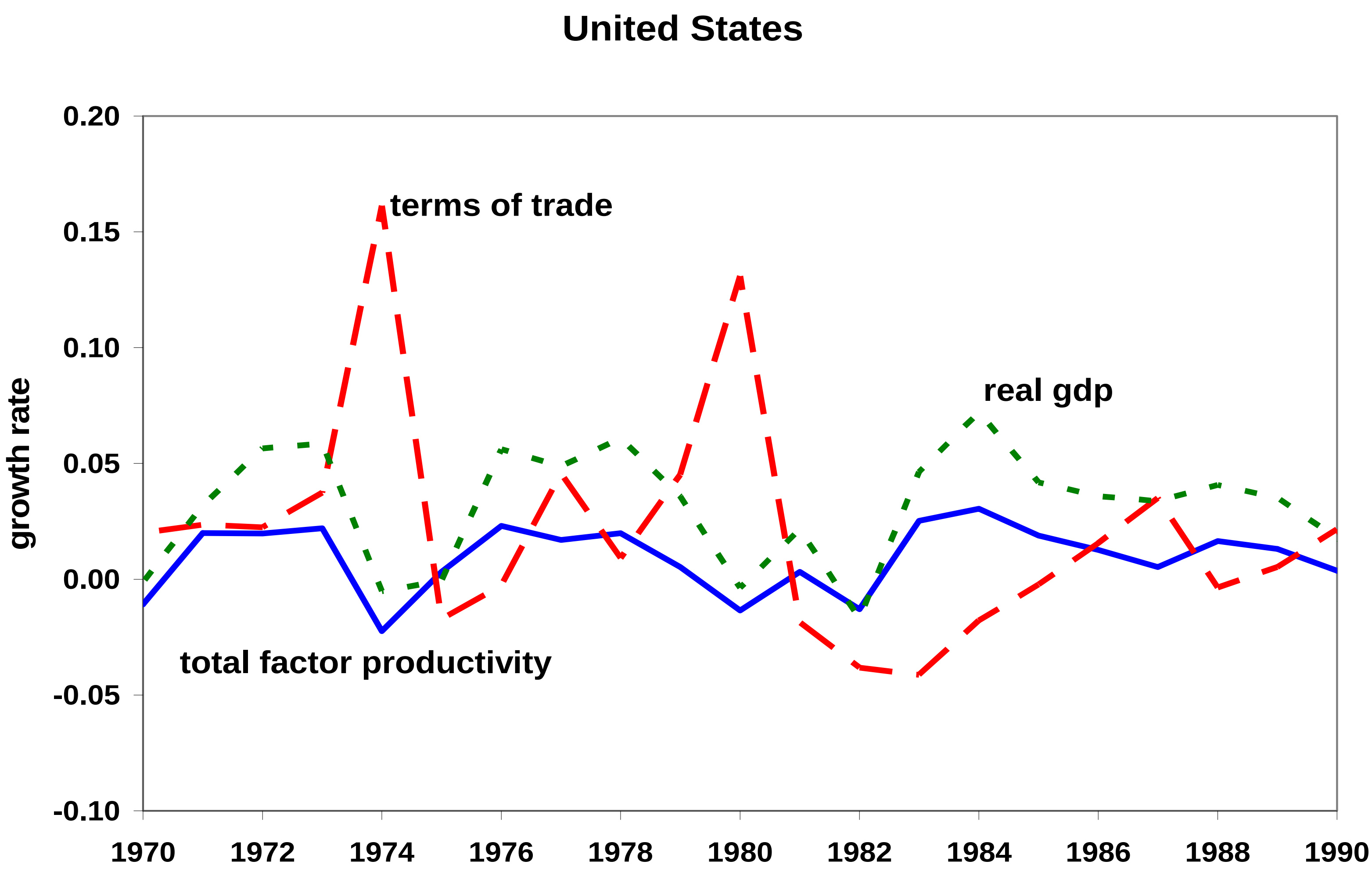
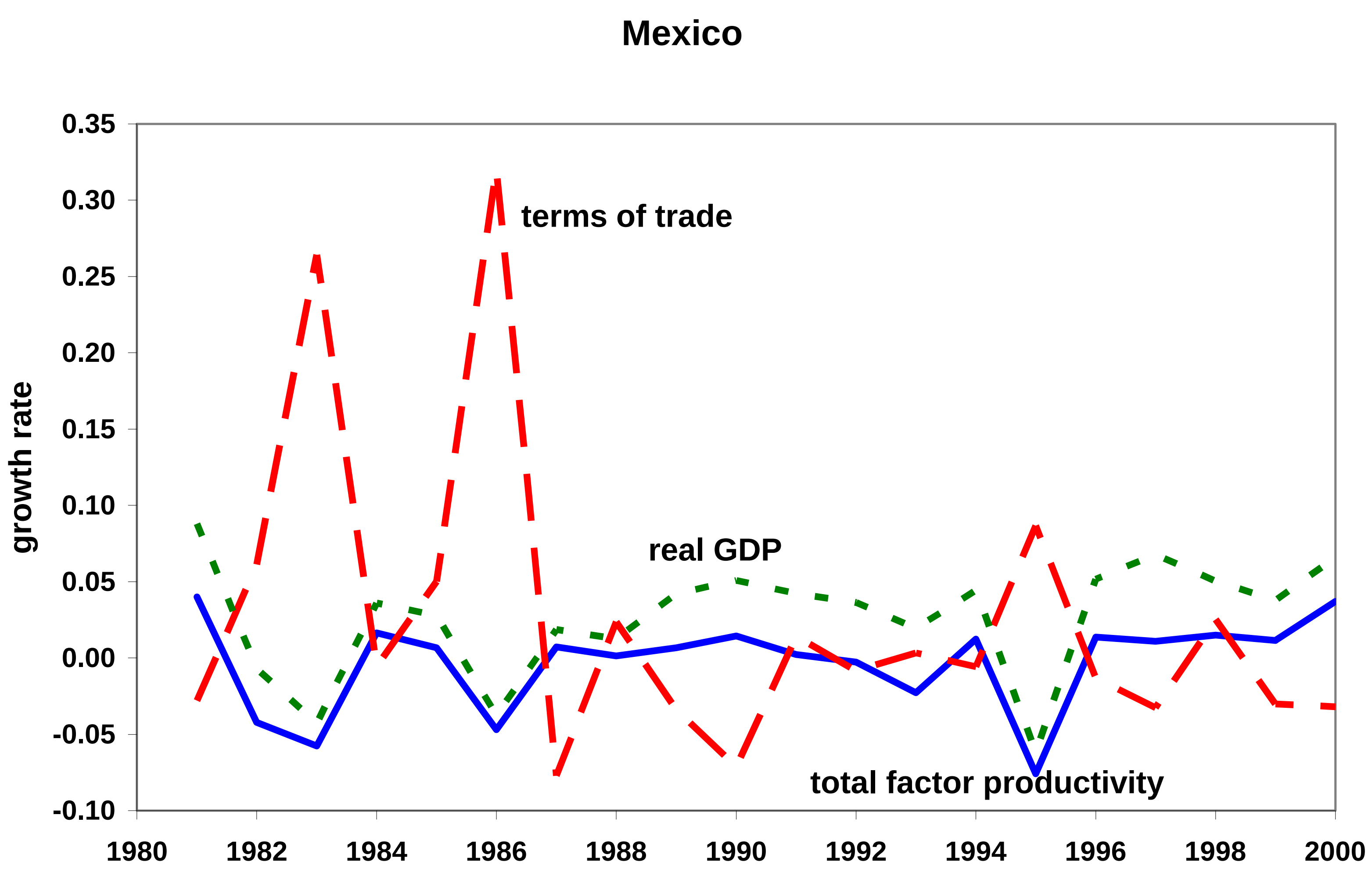
Evidence on terms of trade, GDP, and TFP



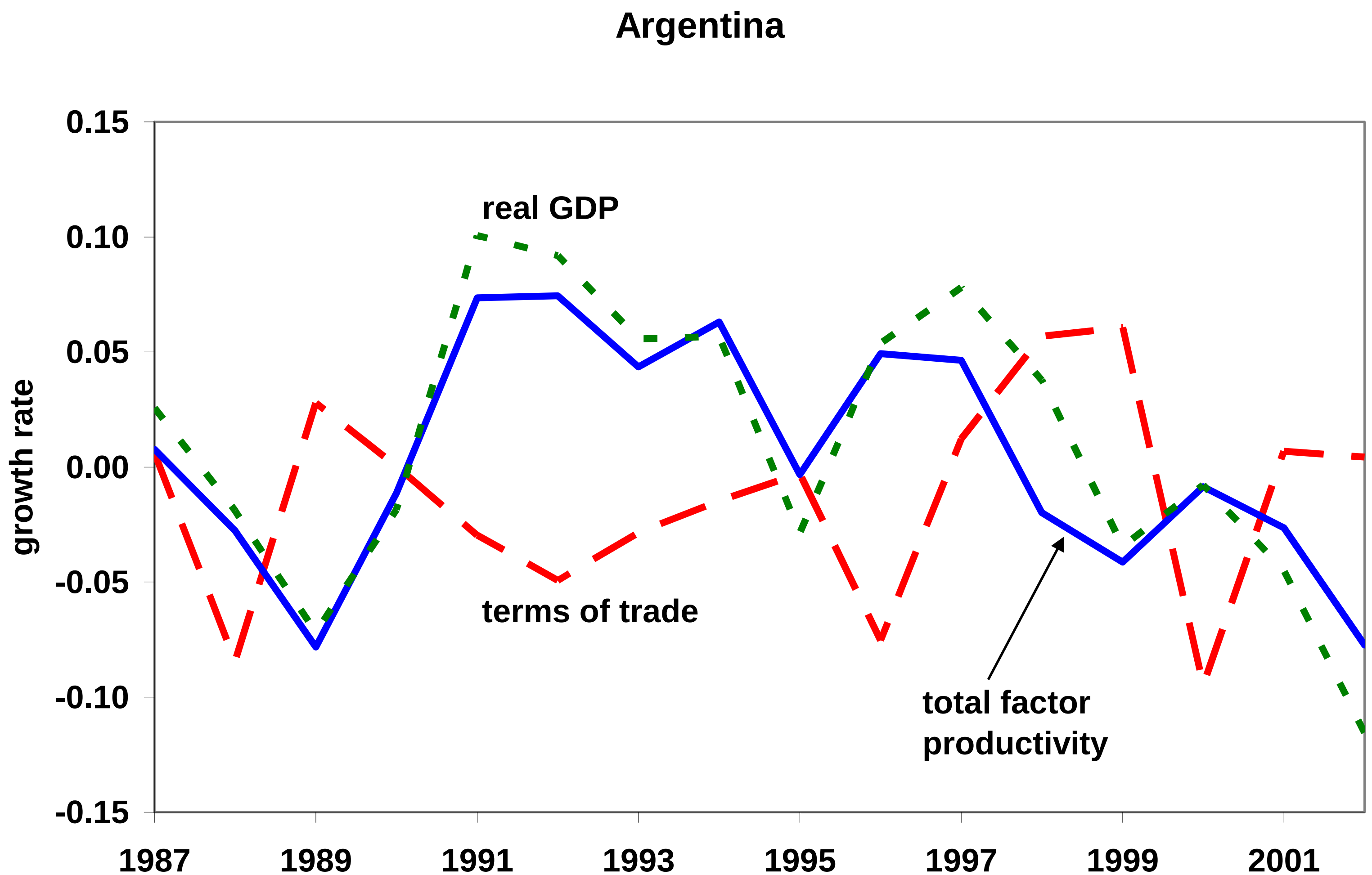
$$\rho\left(tot, tfp\right) = -0.46 \qquad \rho\left(tot, gdp\right) = -0.30$$

Evidence on terms of trade, GDP, and TFP



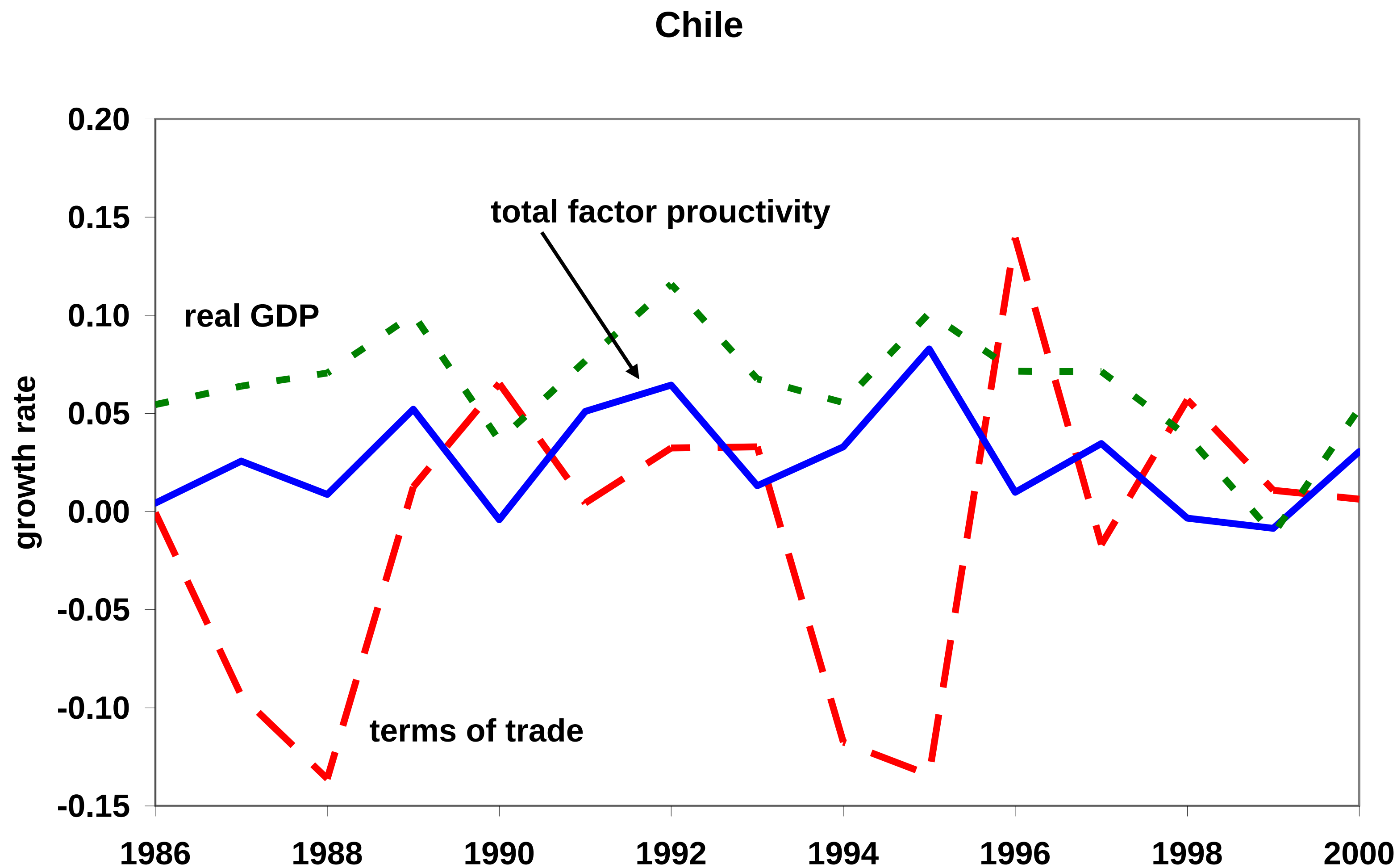
$$\rho(tot, tfp) = -0.73 \qquad \rho(tot, gdp) = -0.75$$

Evidence on terms of trade, GDP, and TFP



$$\rho\left(tot, tfp\right) = -0.39 \qquad \rho\left(tot, gdp\right) = -0.26$$

Evidence on terms of trade, GDP, and TFP



$$\rho(tot, tfp) = -0.37 \qquad \rho(tot, gdp) = -0.17$$

Terms of trade volatility in the world

	std(terms of trade)	std(TFP)
Developing countries	0.132	0.026
Developed countries	0.053	0.017
Ratio	2.49	1.53

Hodrick-Prescott filtered annual data. source: Sengul (2006)

International trade as a production technology

"For small *open* economies, adverse terms of trade shocks can have much the same effect as negative technology shocks, and this is one of the important differences between macroeconomics in these economies and that which underlies some of the traditional closed economy models."

Easterly, Islam, and Stiglitz (2001)

International trade as a production technology

Inputs are exports and outputs are imports.

$$p_t M_t = X_t \;\Rightarrow\; M_t = \frac{1}{p_t} X_t$$

A deterioration in the terms of trade (an increase in p_t) acts as a productivity shock.

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Or does it?

Overview of results

- Changes in p_t have no first order effect on chain weighted GDP or measured productivity.

- With fixed proportions production, result is exact even for large shocks. (Forget about calculus!)

- Without chain weighting, effect involves $p_t - p_0$. (Effect goes either way!)

- With elastically supplied factors of production, effect goes either way.

- Results generalize to changes in tariffs and other trade barriers.

What drives the correlation between p_t and real GDP and TFP?

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Not the mechanism we have discussed!

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These ideas are well understood by economists interested in index numbers and national income accounting.

Diewert and Morrison (1986)

Kohli (1983, 2004)

Roadmap

1. Simple closed economy

2. Model reinterpreted as an open economy

3. Chain weighting

4. Elasticity of substitution

5. Extension: endogenous labor choice

6. Extension: taxes and tariffs

7. Quantitative effects in Mexico

Simple model: Closed economy

$$\ell_t = \overline{\ell}$$

$$y_t = f(\ell_t, m_t)$$

$$m_t = \frac{x_t}{a_t}$$

$$c_t + x_t = y_t$$

Normalize the price of the y good to be 1.

$$p_t = a_t$$

Real GDP:

expenditure side

$$Y_t = c_t = y_t - x_t$$

output side

$$Y_t = \left(y_t + p_0 m_t\right) - \left(p_0 m_t + x_t\right) = y_t - x_t$$

where $p_0 = a_0$

Firms solve

$$\max f(\bar{\ell}, m_t) - a_t m_t$$

$$f_m(\bar{\ell}, m_t) = a_t$$

$$m'(a_t) = \frac{1}{f_{mm}(\bar{\ell}, m(a_t))} < 0$$

With fixed proportions, $y_t = \min\left[\ell_t, m_t / b\right]$,

$$m'(a_t) = 0$$

How does real GDP change?

$$Y(a_{t+1}) - Y(a_t) \approx Y'(a_t)(a_{t+1} - a_t)$$

where

$$Y(a_t) = f(\overline{\ell}, m(a_t)) - a_t m(a_t)$$

$$Y'(a_t) = f_m(\overline{\ell}, m(a_t))m'(a_t) - a_t m'(a_t) - m(a_t) = -m(a_t) < 0.$$

With fixed proportions, $y_t = \min[\ell_t, m_t / b]$,

$$Y(a_t) = \overline{\ell} - a_t b \overline{\ell}$$

$$Y'(a_t) = -b\overline{\ell} = -m_t.$$

Real GDP and productivity decline.

Simple model: Open economy

m_t is an imported intermediate input

x_t are exports of the y good

p_t is the terms of trade

we assume balanced trade,

$$p_t m_t = x_t$$

Real GDP

$$Y_t = c_t + x_t - p_0 m_t = y_t - p_0 m_t = f(\overline{\ell}, m_t) - p_0 m_t$$

An increase in p_t has the identical impact on consumption and welfare as the decline in productivity in the closed economy.

But what happens to real GDP and productivity?

$$Y(p_t) = f(\overline{\ell}, m(p_t)) - p_0 m(p_t)$$

$$Y'(p_t) = f_m(\overline{\ell}, m(p_t)) m'(p_t) - p_0 m'(p_t) = (p_t - p_0) m'(p_t)$$

With fixed proportions,

$$Y(p_t) = \overline{\ell} - p_0 b \overline{\ell}$$

$$Y'(p_t) = 0,$$

but

$$c(p_t) = (1 - p_t b)\overline{\ell}.$$

This is the case where consumption, and therefore welfare, falls the most in response to a deterioration in the terms of trade.

Chain weighted real GDP

NIPA: Fisher chain weights, (UN SNA: Laspeyres chain weights)

$$Y_t(p_t) = \frac{f(\bar{\ell}, m(p_t)) - p_t m(p_t)}{P_t}$$

$$P_{t+1} = \left(\frac{f(\bar{\ell}, m(p_{t+1})) - p_{t+1} m(p_{t+1})}{f(\bar{\ell}, m(p_{t+1})) - p_t m(p_{t+1})} \right)^{\frac{1}{2}} \left(\frac{f(\bar{\ell}, m(p_t)) - p_{t+1} m(p_t)}{f(\bar{\ell}, m(p_t)) - p_t m(p_t)} \right)^{\frac{1}{2}} P_t$$

$$Y(p_{t+1}) = \left(\frac{f(\bar{\ell}, m(p_{t+1})) - p_{t+1} m(p_{t+1})}{f(\bar{\ell}, m(p_t)) - p_{t+1} m(p_t)} \right)^{\frac{1}{2}} \left(\frac{f(\bar{\ell}, m(p_{t+1})) - p_t m(p_{t+1})}{f(\bar{\ell}, m(p_t)) - p_t m(p_t)} \right)^{\frac{1}{2}} Y(p_t)$$

How does real GDP change with p?

$$Y(p_{t+1}) - Y(p_t) \approx Y'(p_t)(p_{t+1} - p_t)$$

$$\frac{d\log Y(p_{t+1})}{dp_{t+1}} = -\frac{m(p_{t+1})}{2\left(f(\overline{\ell}, m(p_t)) - p_t m(p_t)\right)} + \frac{m(p_t)}{2\left(f(\overline{\ell}, m(p_t)) - p_{t+1} m(p_t)\right)} + \frac{(p_{t+1} - p_t)m'(p_{t+1})}{2\left(f(\overline{\ell}, m(p_{t+1})) - p_t m(p_{t+1})\right)}$$

$$\frac{d\log Y\left(p_t\right)}{dp_{t+1}} = 0$$

With any method of chaining, effect involving $p_t - p_0$ disappears.

Elasticity of substitution

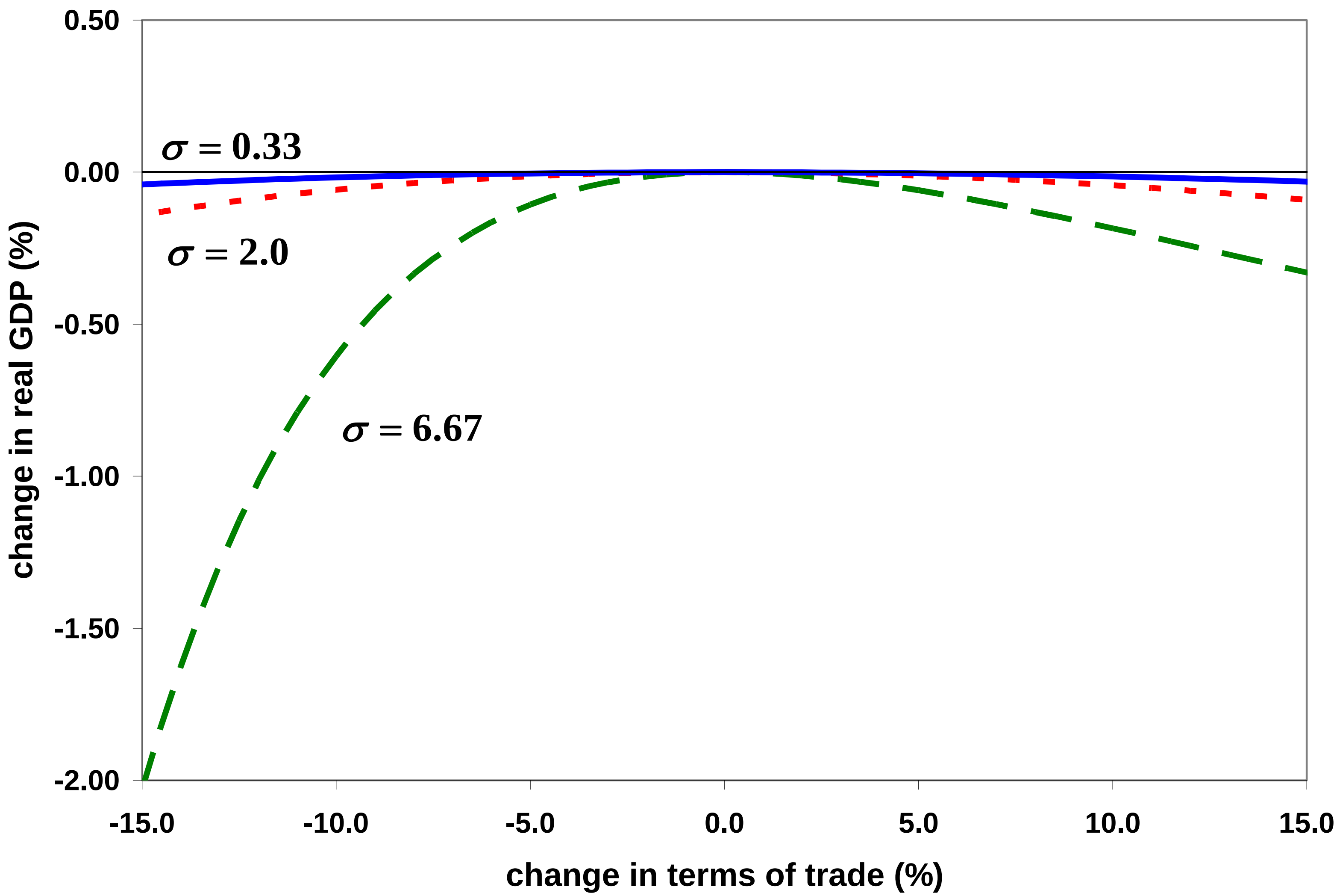
$$f\left(\ell_t, m_t\right) = \left(\left(1-\beta\right)\ell_t^{\rho} + \beta m_t^{\rho}\right)^{\frac{1}{\rho}}$$

For each value of ρ, choose β so that

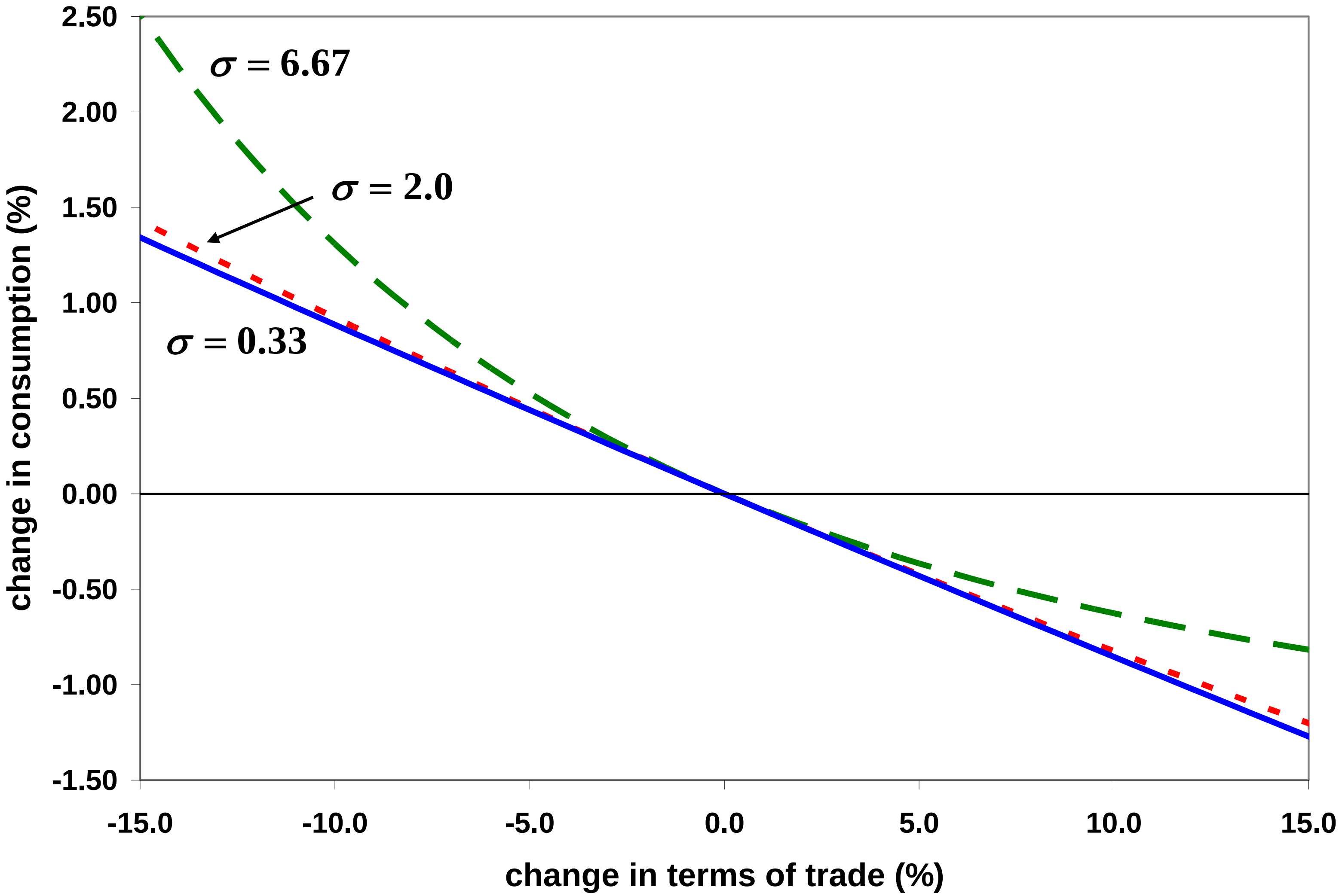
$$\frac{m_t}{\left(\left(1-\beta\right)\ell_t^{\rho} + \beta m_t^{\rho}\right)^{\frac{1}{\rho}}} = 0.08$$

(U.S. data, 1998-2005).

Real GDP and the elasticity of substitution



Consumption and the elasticity of substitution



Extensions to the simple model

Variable labor supply

$$\max u(c_t, \overline{\ell} - \ell_t)$$

$$\text{s.t. } c_t = w_t \overline{\ell}$$

where $w_t = f_\ell(\ell_t, m_t)$.

$$w_t u_c(c_t, \overline{\ell} - \ell_t) = u_z(c_t, \overline{\ell} - \ell_t)$$

which implicitly defines the function $\ell(w)$:

$$w_t u_c(w_t \ell(w_t), \overline{\ell} - \ell(w_t)) = u_z(w_t \ell(w_t), \overline{\ell} - \ell(w_t))$$

$$\ell'(w_t) = -\frac{u_c(c_t, \overline{\ell} - \ell_t) + u_{cc}(c_t, \overline{\ell} - \ell_t) w_t \ell_t - u_{cz}(c_t, \overline{\ell} - \ell_t) \ell_t}{u_{cc}(c_t, \overline{\ell} - \ell v) w_t^2 - 2u_{cz}(c_t, \overline{\ell} - \ell_t) w_t + u_{zz}(c_t, \overline{\ell} - \ell_t)}.$$

C. E. S. case

$$u(c,z) = \begin{cases} \left(c^{\rho} + \gamma z^{\rho} - 1 - \gamma\right)/\rho & \text{for } \rho \le 1,\ \rho \ne 0 \\ \log c + \gamma \log z & \text{for } \rho = 0 \end{cases}$$

$$\ell'(w) = \frac{\rho c^{\rho-1}}{(1-\rho)\left(w^2 c^{\rho-2} + \gamma(\overline{\ell} - \ell)^{\rho-2}\right)}$$

$\ell'(w)$ has same sign as ρ.

How do w and m vary with p?

$$f_\ell(\ell(w(p)),m(p)) = w(p)$$

$$f_m(\ell(w(p)),m(p))) = p$$

$$f_{\ell\ell}(\ell,m)\ell'(w)w'(p) + f_{\ell m}(\ell,m)m'(p) = w'(p)$$

$$f_{\ell m}(\ell,m)\ell'(w)w'(p) + f_{mm}(\ell,m)m'(p) = 1$$

$$w'(p) = \frac{f_{\ell m}(\ell,m)}{f_{mm}(\ell,m) - \left(f_{mm}(\ell,m) f_{\ell\ell}(\ell,m) - f_{\ell m}(\ell,m)^2 \right)\ell'(w)}$$

$$m'(p) = \frac{1 - f_{\ell\ell}(\ell,m)\ell'(w)}{f_{mm}(\ell,m) - \left(f_{mm}(\ell,m) f_{\ell\ell}(\ell,m) - f_{\ell m}(\ell,m)^2 \right)\ell'(w)}$$

Consumer welfare:

$$c(p) = f(\ell(w(p)), m) - pm(p)$$

$$\frac{d}{dp}u(c(p_t), \overline{\ell} - \ell(w(p_t))) = -u_c(c_t, \overline{\ell} - \ell_t)m_t < 0.$$

Real GDP:

$$Y(p_t) = f(\ell(w(p_t)), m(p_t)) - p_0 m(p_t)$$

$$Y'(p_t) = f_\ell(\ell_t, m_t)\ell'(w_t)w'(p_t) + (p_t - p_0)m'(p_t)$$

Real GDP can either rise or fall with p_t

If $\ell'(w_t) > 0$, which implies that $w'(p_t) < 0$, and if $(p_t - p_0)m'(p_t)$ is small, real GDP falls.

Productivity:

$$Y(p_t)/\ell(w(p_t))$$

$$\frac{d}{dp_t}\frac{Y(p_t)}{\ell(w(p_t))} = \frac{\ell(w_t)Y'(p_t) - Y(p_t)\ell'(w_t)w'(p_t)}{\ell(w_t)^2}$$

$$\frac{d}{dp_t}\frac{Y(p_t)}{\ell(w(p_t))} = \frac{(p_t - p_0)\left(\ell_t m'(p_t) - m_{t-1}\ell'(w_t)w'(p_t)\right)}{\ell_t^2}.$$

with fixed proportions case,

$$Y(p_t) = (1 - p_0 b)\ell(w(p_t))$$

Tariffs

$$\max f(\bar{\ell}, m_t) - (1+\tau_t) p_t m_t$$

Real GDP:

$$Y'(p_t) = ((1+\tau) p_t - p_0) m'(p_t)$$

$$Y'(\tau_t) = ((1+\tau_t) p_t - p_0) m'(\tau_t)$$

≈ 0 if $(1+\tau_t) p_t - p_0 \approx 0$ or if f is close to fixed proportions.

Welfare:

$$c'(p_t) = \tau p_t m'((1+\tau) p_t) - m(p_t (1+\tau)) p_t)$$

$$c'(\tau_t) = \tau_t p_t m'((1+\tau_t) p_t)$$

Alternative income measures

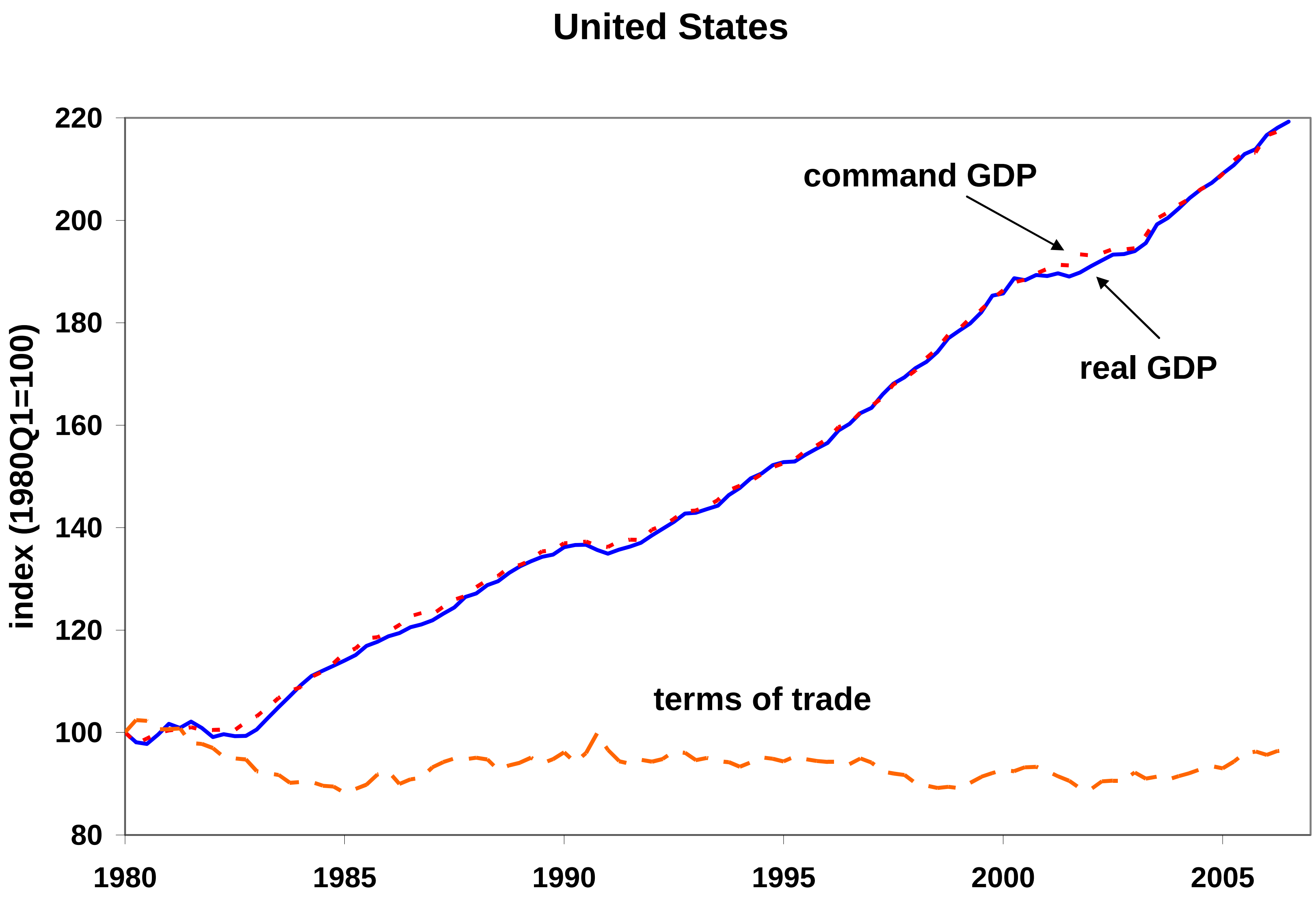
U.S. NIPA: command-basis GDP

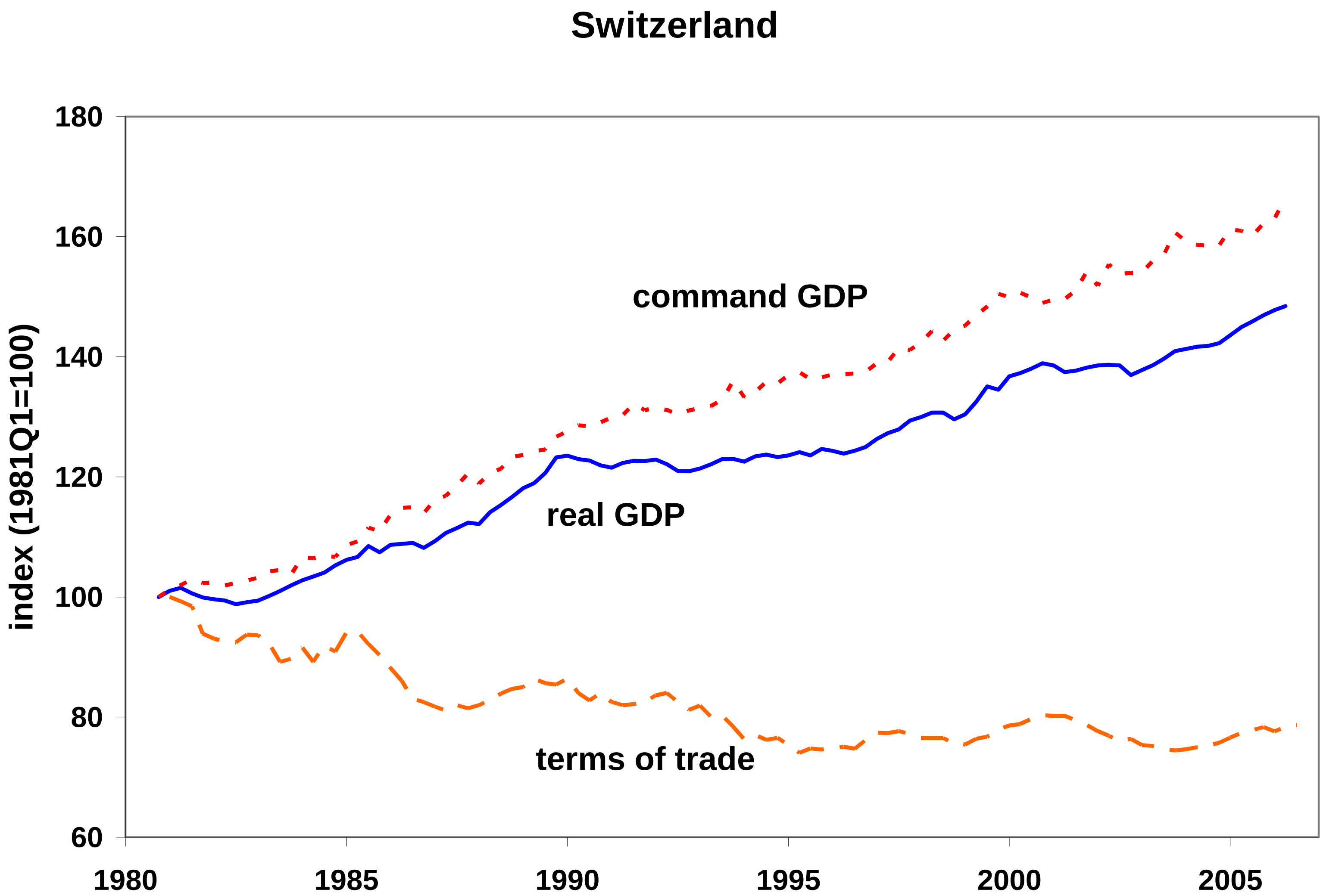
U.N. SNA: Gross Domestic Income

$$GDP_t = \frac{C_t}{P_t^C} + \frac{I_t}{P_t^I} + \frac{G_t}{P_t^G} + \frac{X_t}{P_t^X} - \frac{M_t}{P_t^M}$$

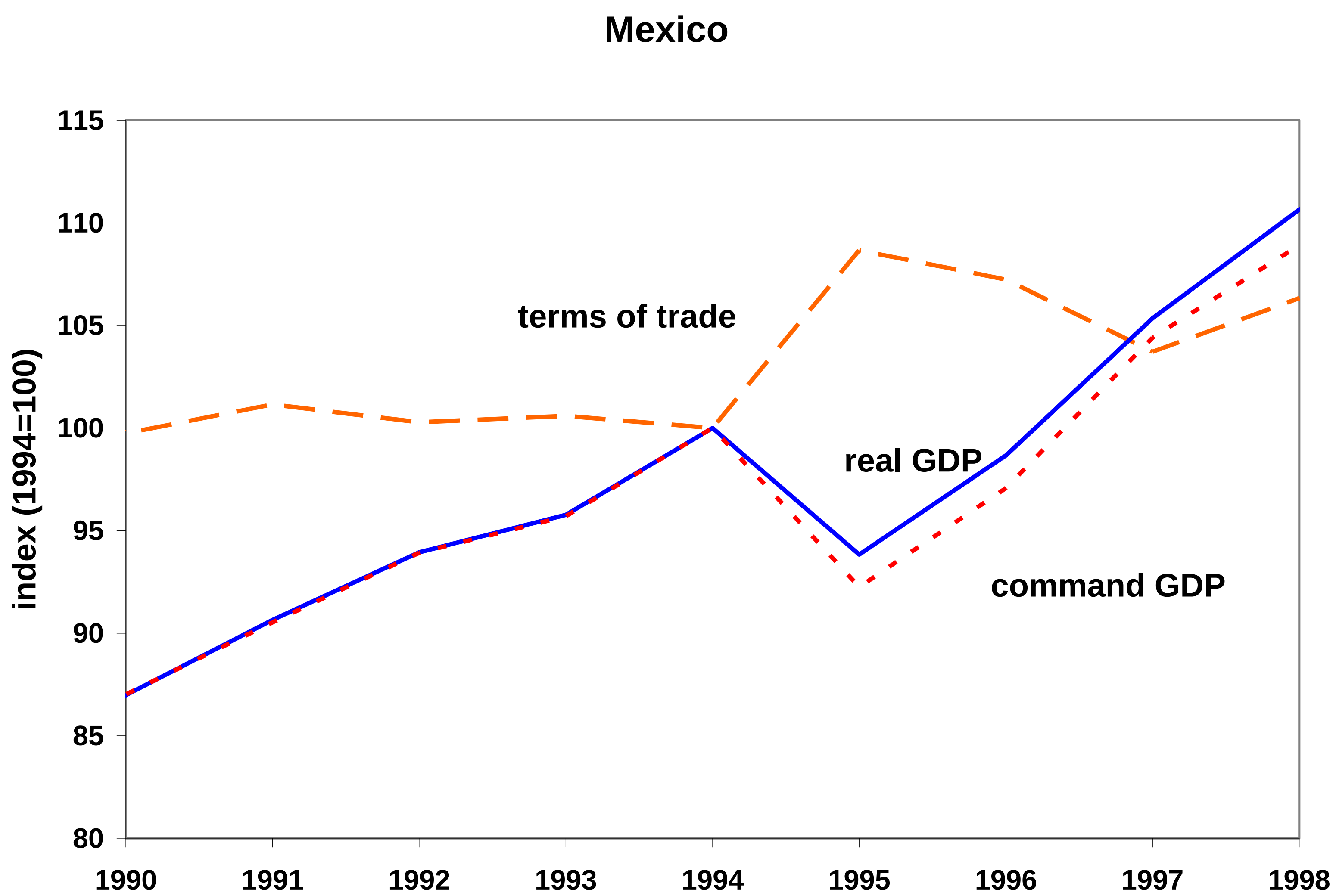
$$GDI_t = \frac{C_t}{P_t^C} + \frac{I_t}{P_t^I} + \frac{G_t}{P_t^G} + \frac{X_t - M_t}{P_t^M}.$$

or deflate $X_t - M_t$ by P_t^Y or deflate $X_t - M_t$ by P_t^X, or…

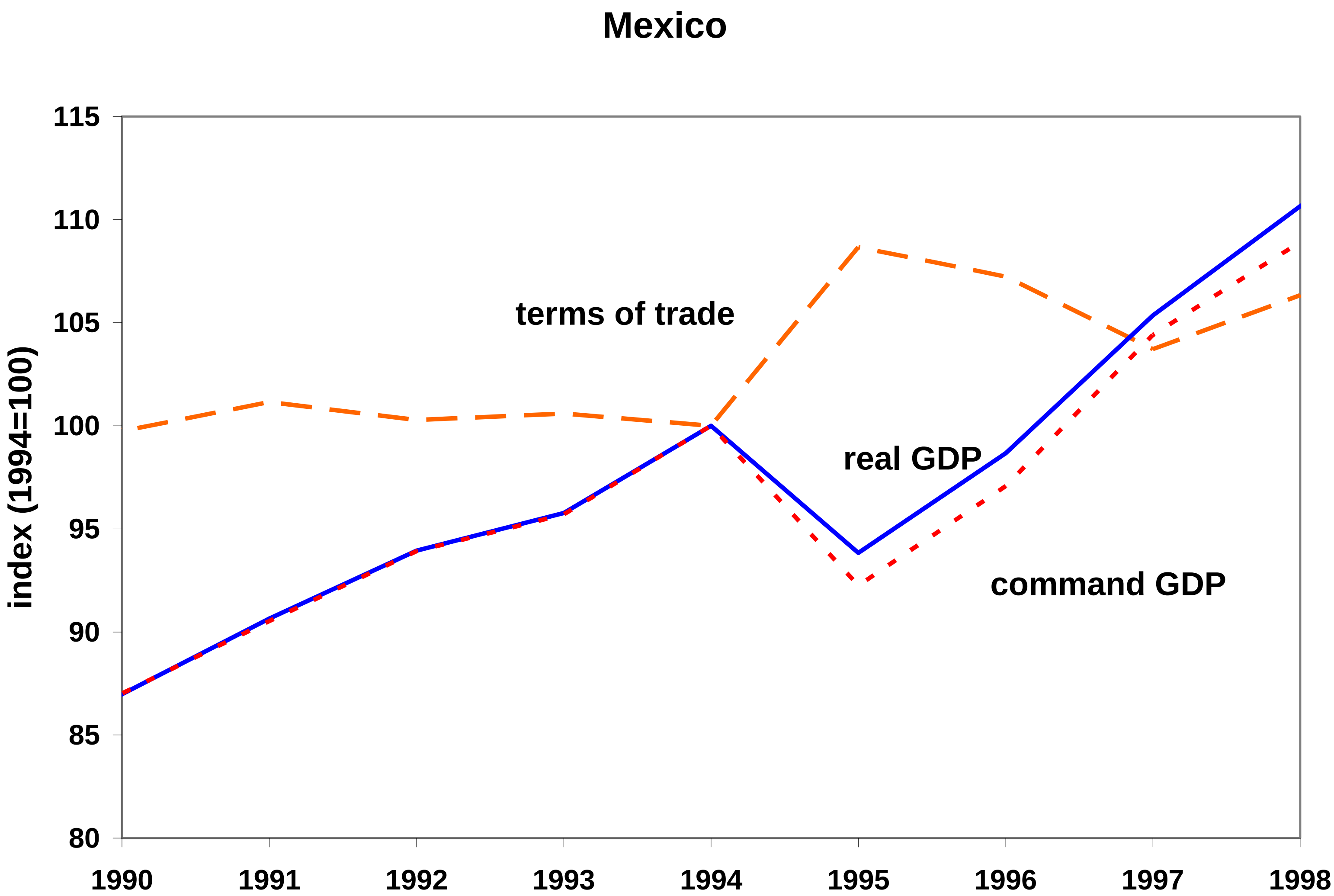

United States
command GDP
real GDP
terms of trade
index (1980Q1=100)
220
200
180
160
140
120
100
80
1980
1985
1990
1995
2000
2005



Switzerland
180
160
140
120
100
80
60
index (1981Q1=100)
command GDP
real GDP
terms of trade
1980
1985
1990
1995
2000
2005



Mexico
index (1994=100)
115
110
105
100
95
90
85
80
1990
1991
1992
1993
1994
1995
1996
1997
1998
terms of trade
real GDP
command GDP



Terms of trade shocks are worse than you thought!

Quantitative Example

Open Economy Model

Two kinds of goods:

- Imports ($m-$goods)
- Domestically produced goods ($d-$goods)

Domestic good is the numeraire

- The terms of trade, p_m, is exogenous

Add 3 exogenous variables

- Terms of trade, $p_{m,t}$
- Productivity – not TFP!!
- Investment-consumption good productivity, D_t

Open Economy Model

Households

$$\max \sum_{t=T_0}^{\infty} \beta^t \left(\gamma \log\left(C_t\right) + \left(1-\gamma\right) \log(\bar{h} N_t - L_t) \right)$$

$$\text{s.t. } q_t C_t + q_t (K_{t+1} - (1-\delta) K_t) = w_t L_t + r_t K_t$$

Domestic Good Technology

$$Z_t + X_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

Feasibility

$$C_t + K_{t+1} - (1-\delta) K_t = D_t \left(\omega Z_t^{\rho} + \left(1-\omega\right) M_t^{\rho} \right)^{\frac{1}{\rho}}$$

The firm's problem

$$\min_{Z_t, M_t} \quad \mathrm{Z}_t + p_{m,t} M_t$$

$$\text{s.t.} \quad \bar{\mathrm{Y}}_t \leq D_t \left(\omega Z_t^{\rho} + (1-\omega) M_t^{\rho} \right)^{\frac{1}{\rho}}$$

Investment-consumption good price

$$q_t = D_t^{-1} \left(\omega^{\frac{1}{1-\rho}} + (1-\omega)^{\frac{1}{1-\rho}} \, p_{m,t}^{\frac{-\rho}{1-\rho}} \right)^{\frac{1-\rho}{-\rho}}$$

Open Economy Model Calibration

Exogenous processes

- Terms of trade, $p_{m,t}$, from data
- Productivity in investment-consumption sector, D_t, from data
- Productivity in the domestic sector, A_t

Exogenous productivity is

$$A_t = \frac{\omega^{-\frac{1}{\rho}}\left(\left(C_t + I_t\right)^{\rho} D_t^{-\rho} - \left(1-\omega\right) M_t^{\ \rho}\right)^{\frac{1}{\rho}} + X_t}{K_t^{\ \alpha} L_t^{1-\alpha}}$$

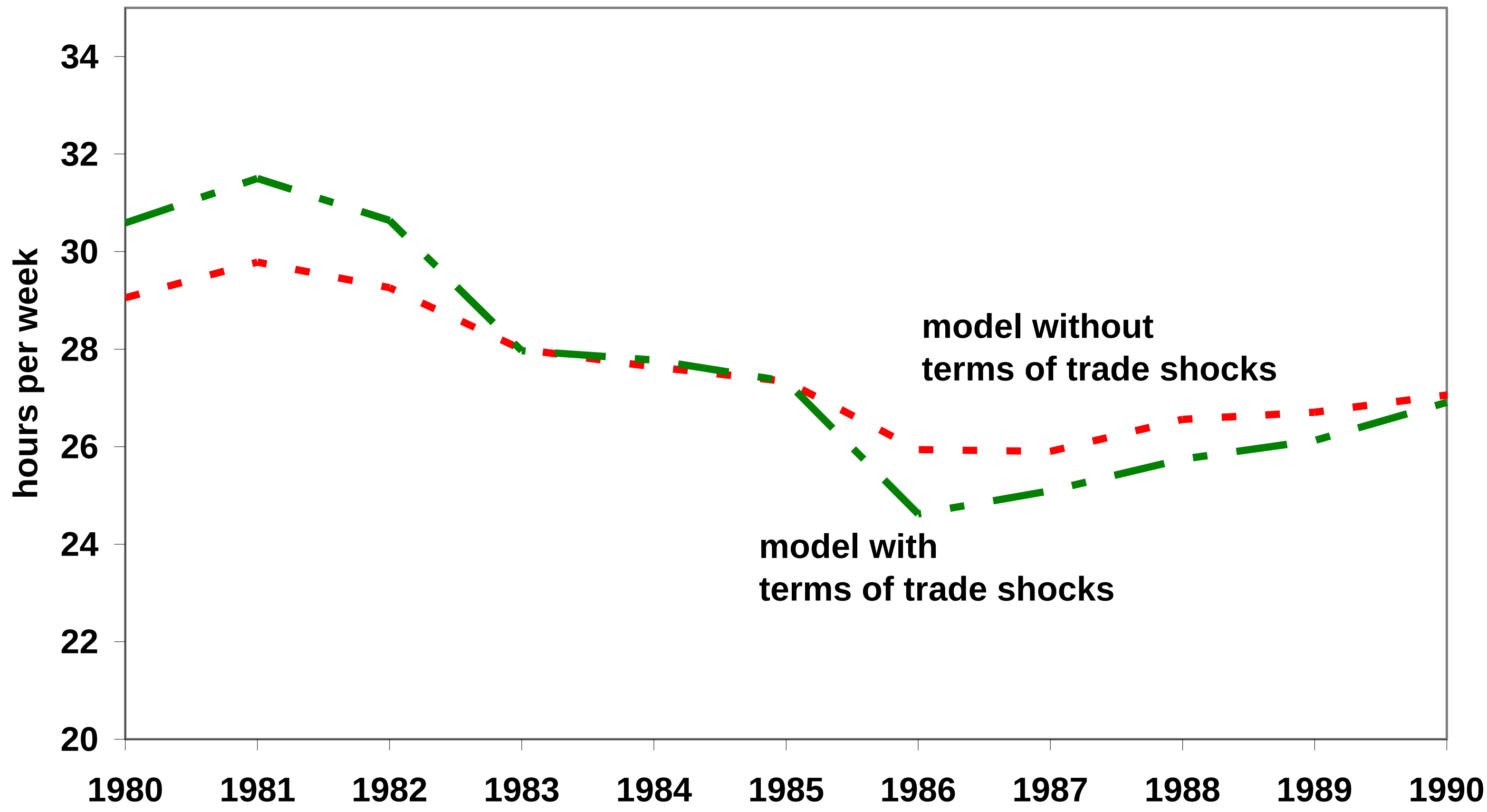
TFP is calculated with real GDP: $\hat{Y}_t = q_{\bar{T}}\left(C_t + I_t\right) + X_t - p_{m,\bar{T}} M_t$

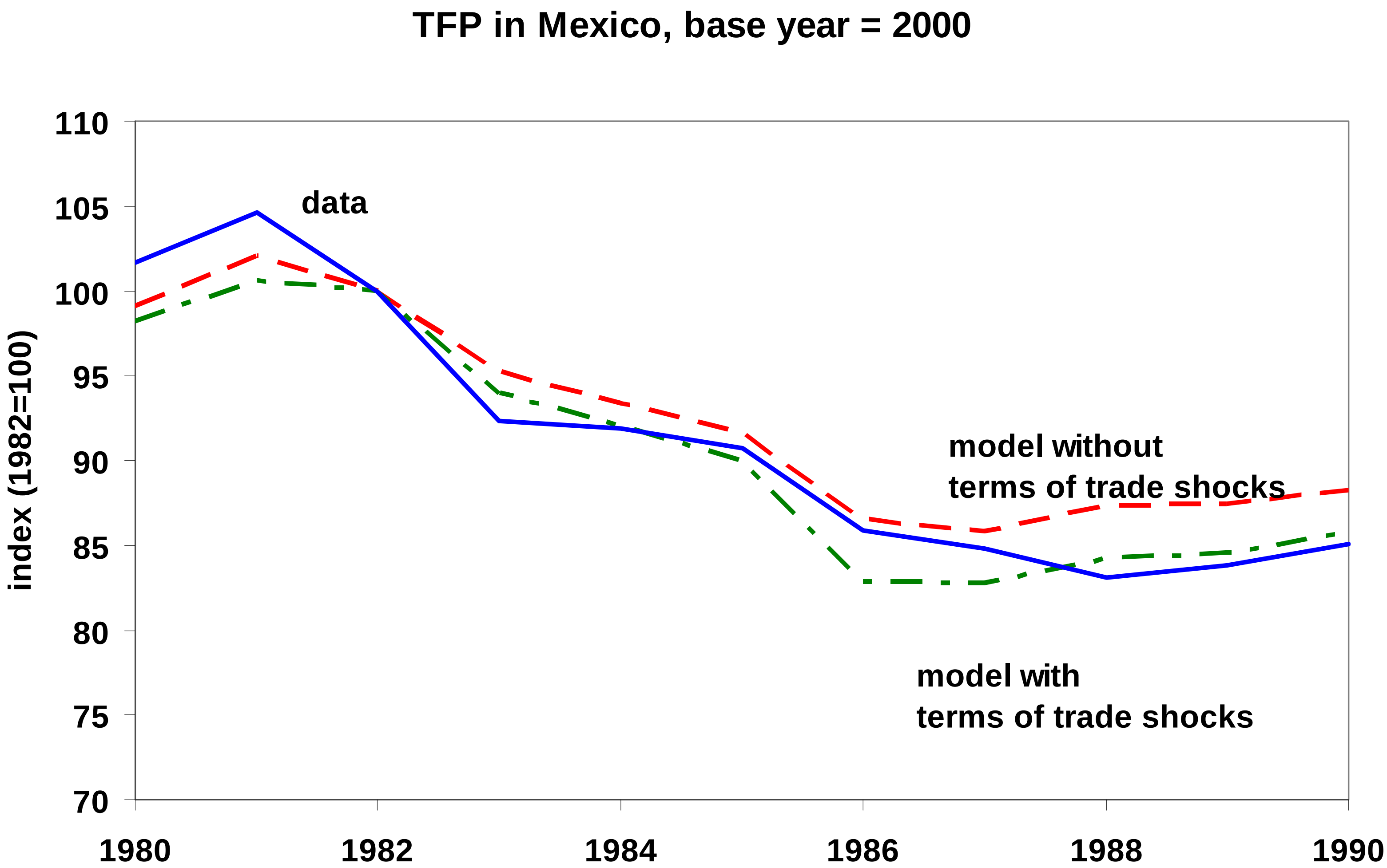
Solve the model two ways:

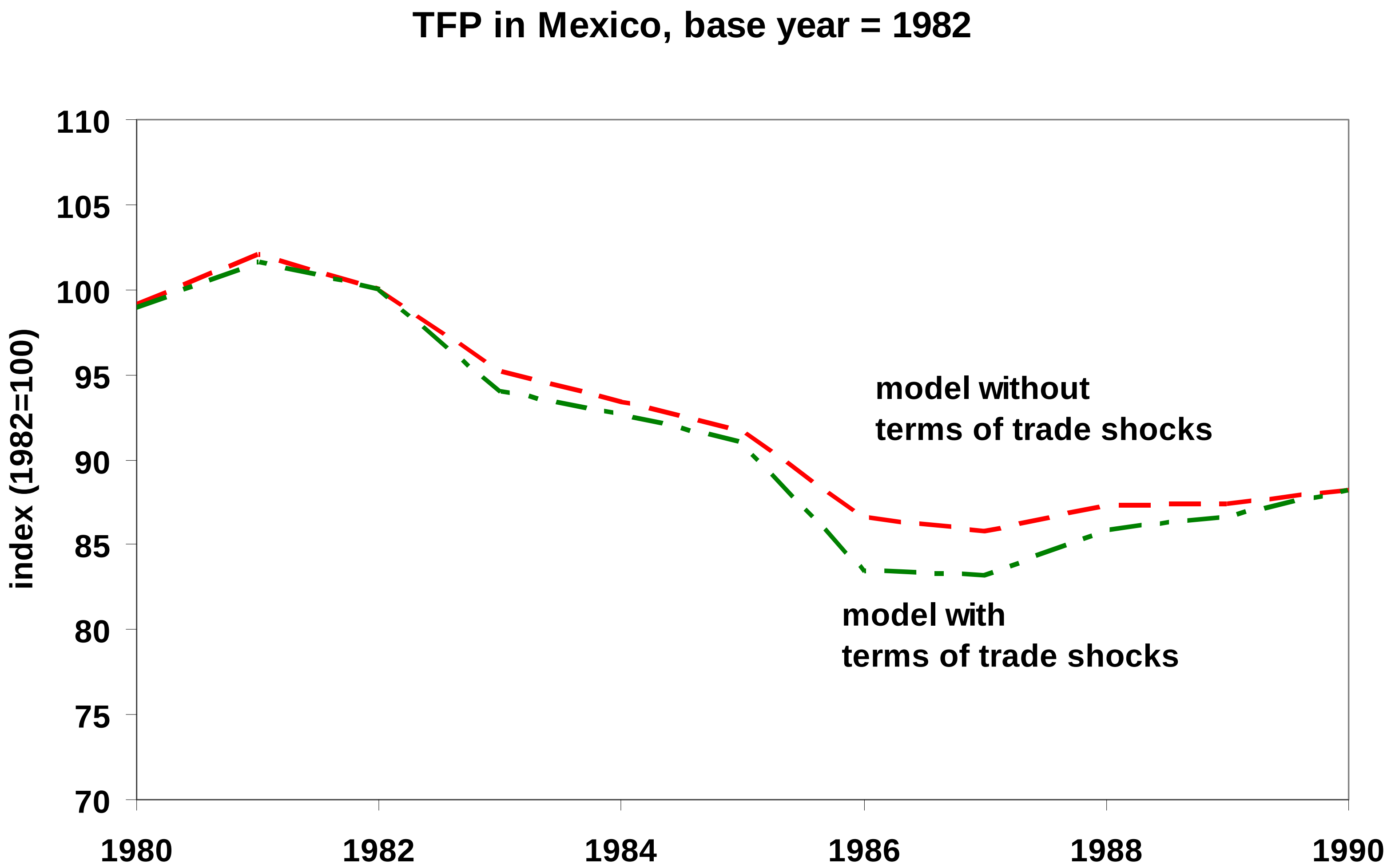
1. Model with terms of trade shocks
2. Model without terms of trade shocks (do not recalibrate)


Real GDP per working age person in Mexico
index (1982=100)
120
110
100
90
80
70
60
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
model with
terms of trade shocks
model without
terms of trade shocks

Hours worked per working age person in Mexico

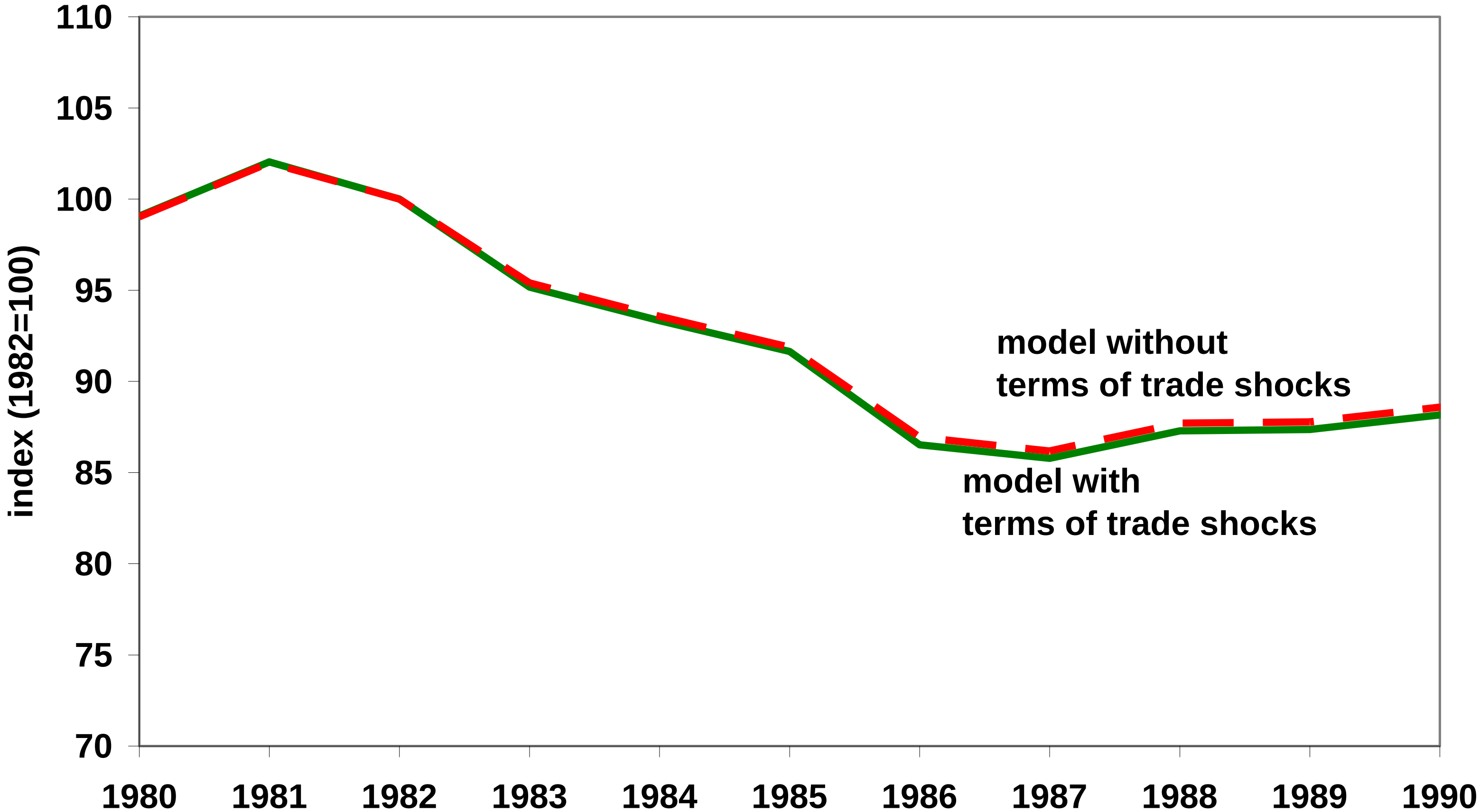



TFP in Mexico, base year = 2000
index (1982=100)
110
105
100
95
90
85
80
75
70
1980
1982
1984
1986
1988
1990
data
model without
terms of trade shocks
model with
terms of trade shocks



TFP in Mexico, base year = 1982
index (1982=100)
110
105
100
95
90
85
80
75
70
1980
1982
1984
1986
1988
1990
model without
terms of trade shocks
model with
terms of trade shocks

TFP in Mexico, chain weighted



Conclusion

Base period prices: terms of trade have an ambiguous effect on TFP

Chain weighting: terms of trade have no effect on TFP

Terms of trade shocks can increase GDP volatility, but only by changing factor inputs, not productivity.