

# Small Open Economy Extension (IRBC)

Macro II - Fluctuations - ENSAE, 2024-2025

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## Introduction and Basic Facts

# Why a small open economy?

What are the classical reasons to open economy to trade?

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  - ▶ comparative advantage
- ▶ financial integration
  - ▶ smooth shock / insurance

## From RBC to IRBC

RBC models have been very successful at matching Business Cycles

- ▶ (temporary) victory against keynesian view that short term fluctuations result from demand shocks
- ▶ so successful that facts at odd with theoretical predictions have been called “puzzles”



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Seminal Paper:

- ▶ *International Real Business Cycles*, Backus, Kehoe, Kydland (1992) (freshwater economists)

Very successful methodology:

- ▶ facts at odd with theoretical predictions have been called “puzzles”

# IRBC Facts

Properties of Business Cycles in OECD Economies

Country	Std. Dev. (%)		Ratio of Standard Deviation to that of y					Autocorr. y	Correlation with Output					
	y	nx	c	x	g	n	z		c	x	g	nx	n	z
Australia	1.45	1.23	.66	2.78	1.28	.34	1.00	.60	.46	.68	.15	-.01	.12	.98
Austria	1.28	1.15	1.14	2.92	.36	1.23	.84	.57	.65	.75	-.24	-.46	.58	.65
Canada	1.50	.78	.85	2.80	.77	.86	.74	.79	.83	.52	-.23	-.26	.69	.84
France	.90	.82	.99	2.96	.71	.55	.76	.78	.61	.79	.25	-.30	.77	.96
Germany	1.51	.79	.90	2.93	.81	.61	.83	.65	.66	.84	.26	-.11	.59	.93
Italy	1.69	1.33	.78	1.95	.42	.44	.92	.85	.82	.86	.01	-.68	.42	.96
Japan	1.35	.93	1.09	2.41	.79	.36	.88	.80	.80	.90	-.02	-.22	.60	.98
Switzerland	1.92	1.32	.74	2.30	.53	.71	.67	.90	.81	.82	.27	-.68	.84	.93
U.K.	1.61	1.19	1.15	2.29	.69	.68	.88	.63	.74	.59	.05	-.19	.47	.90
U.S.	1.92	.52	.75	3.27	.75	.61	.68	.86	.82	.94	.12	-.37	.88	.96
Europe	1.01	.50	.83	2.09	.47	.85	.98	.75	.81	.89	.10	-.25	.32	.85

Notes: Statistics are based on Hodrick-Prescott filtered data. Variables are: y, real output; c, real consumption; x, real fixed investment; g, real government purchases; nx, ratio of net exports to output, both at current prices; n, civilian employment; z, Solow residual, defined in text. Except for the ratio of net exports to output, statistics refer to logarithms of variables. Data are quarterly from the OECD's *Quarterly National Accounts*, except employment, which is from the OECD's *Main Economic Indicators*. The sample period is 1970:1 to 1990:2.

Figure 1: Moments

From Kehoe, Kydland (1995)

# IRBC Facts

Properties of Business Cycles in OECD Economies

Country	Year (1970-1990)	Actual Business Cycles (1970-1990)					Predictions with Regime				
		1	2	3	4	5	1	2	3	4	5
Australia	1.12	1.25	2.0	1.25	2.0	1.25	1.25	1.25	1.25	1.25	1.25
Austria	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Canada	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
France	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Germany	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Italy	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Japan	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Switzerland	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
United Kingdom	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Europe	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12

## International Comovements in OECD Economies

Country	Correlation with Same U.S. Variable					
	y	c	x	g	n	z
Australia	.51	-.19	.16	.23	-.18	.52
Austria	.38	.23	.46	.29	.47	.17
Canada	.76	.49	-.01	-.01	.53	.75
France	.41	.39	.22	-.20	.26	.39
Germany	.69	.49	.55	.28	.52	.65
Italy	.41	.02	.31	.09	-.01	.35
Japan	.60	.44	.56	.11	.32	.58
Switzerland	.42	.40	.38	.01	.36	.43
United Kingdom	.55	.42	.40	-.04	.69	.35
Europe	.66	.51	.53	.18	.33	.56

Notes: See Table 1.

## Figure 3: Comoments

Figure 2:  
Moments

# Stylized Facts

Report of National Accounts to OECD Economies

Country	Est. Year	Ratio of Household Expenditure to GDP					Estimate	Corresponding ratio Europe				
		1970	1975	1980	1985	1990		1970	1975	1980	1985	1990
Australia	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Canada	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
France	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Germany	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Italy	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Japan	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Netherlands	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
U.K.	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
U.S.	1970	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Domestically:

► output more variable than consumption

Figure 4:  
Moments

International Comparisons in OECD Economies

Country	Correlation with Euro U.S. Variables				
	1	2	3	4	5
Australia	21	-29	28	23	-18
Canada	18	21	20	20	17
France	16	40	-26	-23	20
Germany	41	29	22	-22	26
Italy	41	32	21	29	-16
Japan	46	44	36	21	28
Netherlands	42	49	38	31	26
United Kingdom	33	42	40	-26	23
U.S.	40	21	23	18	20

Internationally:

Figure 5:  
Comoments

## Stylized Facts

	Int. Dev. (FDI)	Relative Business Services Industrialized	Internet	Financial sector (Banks)
Country	1	2	3	4
Australia	1.04	1.23	0.70	1.39
Canada	1.00	1.00	0.70	1.00
France	1.00	1.00	0.40	1.00
Germany	0.92	0.76	0.91	0.99
Italy	1.00	1.00	0.81	0.93
Japan	1.00	1.00	0.50	1.00
UK	1.00	1.00	0.41	0.99
USA	1.00	1.00	0.41	0.99
Sweden	1.00	1.00	0.41	0.99
Finland	1.00	1.00	0.41	0.99
Netherlands	1.00	1.00	0.41	0.99
S.E. Korea	1.00	1.00	0.41	0.99
Spain	1.00	1.00	0.41	0.99
Portugal	1.00	1.00	0.41	0.99
Greece	1.00	1.00	0.41	0.99
Turkey	1.00	1.00	0.41	0.99
China	1.00	1.00	0.41	0.99
India	1.00	1.00	0.41	0.99
South Africa	1.00	1.00	0.41	0.99
South Korea	1.00	1.00	0.41	0.99
Thailand	1.00	1.00	0.41	0.99
Indonesia	1.00	1.00	0.41	0.99
Malaysia	1.00	1.00	0.41	0.99
Singapore	1.00	1.00	0.41	0.99
Taiwan	1.00	1.00	0.41	0.99
Hong Kong	1.00	1.00	0.41	0.99
Macau	1.00	1.00	0.41	0.99
Philippines	1.00	1.00	0.41	0.99
Vietnam	1.00	1.00	0.41	0.99
Laos	1.00	1.00	0.41	0.99
Myanmar	1.00	1.00	0.41	0.99
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Laos	1.00	1.00	0.41	0.99
Myanmar	1.00	1.00	0.41	0.99
Burma	1.00	1.00	0.41	

[illegible]

Figure 4:  
Moments

Country	Correlation with Euro U.S. Variable					
	y	t	s	g	v	i
Australia	.21	-.19	.18	.20	-.18	.22
Austria	.34	.20	.48	.29	.47	.17
Canada	.58	.49	-.81	-.51	.50	.73
France	.41	.39	.52	-.20	.36	.39
Germany	.40	.49	.31	.28	.32	.48
Italy	.41	.32	.21	.39	-.31	.33
Japan	.80	.44	.56	.11	.30	.38
Netherlands	.42	.48	.39	.31	.36	.43
United Kingdom	.53	.42	.48	-.56	.49	.33
Europe	.60	.31	.53	.18	.20	.46

Source: See Table 1.

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated

Internationally:

Figure 5:  
Comoments

## Stylized Facts

	Std. Dev. (%)		Relative Standard Deviation (in %)		Asymmetry		Persistence (Lag Length)	
Country	1	2	3	4	5	6	7	8
Australia	1.04	1.23	0.80	3.70	1.39	1.00	1	1
Canada	1.04	1.23	0.80	3.70	1.39	1.00	1	1
France	1.06	1.19	0.80	3.60	1.38	1.00	1	1
Germany	1.05	1.20	0.80	3.60	1.38	1.00	1	1
Italy	1.02	1.20	0.80	3.60	1.38	1.00	1	1
Japan	1.04	1.23	0.80	3.70	1.39	1.00	1	1
Spain	1.04	1.23	0.80	3.70	1.39	1.00	1	1
Sweden	1.04	1.23	0.80	3.70	1.39	1.00	1	1
Switzerland	1.04	1.23	0.80	3.70	1.39	1.00	1	1
United Kingdom	1.04	1.23	0.80	3.70	1.39	1.00	1	1
United States	1.04	1.23	0.80	3.70	1.39	1.00	1	1
West Germany	1.04	1.23	0.80	3.70	1.39	1.00	1	1
Yugoslavia	1.04	1.23	0.80	3.70	1.39	1.00	1	1

Notes: Statistics are based on RUSHS Panel Study data. Variables are: y, real output; x, real consumption; c, real consumption/capita; s, real government purchases per capita or as percent of output; debt, debt as percent of GDP; d, debt accumulation; r, return on capital; delta, depreciation rate. The full set of variables used in the model can be found at <http://www.rushs.org.uk>. Though the use of debt as a variable is debatable, it is included in the literature of welfare. Data are quarterly from 1970 to 1998. Quarterly National Accounts, except employment, which is from the OPCS's other sources database. The sample period is 1970:1-1998:4.

Figure 4:  
Moments

Country	Correlation with Same U.S. Variable					
	y	a	b	g	v	i
Australia	.71	-.19	.18	.20	-.18	.32
Austria	.58	.20	.48	.29	.47	.17
Canada	.58	.49	-.81	-.51	.50	.73
France	.41	.39	.52	-.20	.36	.39
Germany	.40	.49	.50	.28	.32	.48
Italy	.41	.32	.31	.39	-.31	.33
Japan	.80	.44	.56	.11	.30	.38
Netherlands	.42	.48	.39	.35	.36	.43
United Kingdom	.53	.42	.48	-.56	.49	.32
Europe	.86	.21	.23	.19	.20	.56

Source: See Table 1.

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical

Internationally:

Figure 5:  
Comoments

# Stylized Facts

Properties of National Accounts & 1980-1990 Data

Country	Year	Ratio of National Accounts					Variable	Correlation with Output				
		Y	C	I	G	X		Y	C	I	G	X
Australia	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
Canada	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
France	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
Germany	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
Italy	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
Japan	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
UK	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00
USA	1980	1.00	0.60	0.20	0.20	0.00	Y	1.00	0.60	0.20	0.20	0.00

Note: Ratios are based on 1980-1990 data. Correlation is 1980-1990 correlation. Y, C, I, G, X are national accounts variables. Y is output, C is consumption, I is investment, G is government expenditure, X is exports. All variables are in 1980-1990 data. Correlation is 1980-1990 correlation. Y is output, C is consumption, I is investment, G is government expenditure, X is exports. All variables are in 1980-1990 data. Correlation is 1980-1990 correlation.

Figure 4:  
Moments

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical
- ▶ trade balance strongly countercyclical

International Comovements in OECD Economies

Country	Correlation with US Data (1980-1990)				
	Y	C	I	G	X
Australia	.21	-.29	.28	.22	-.18
Canada	.18	.21	.40	.20	.17
France	.16	.40	-.24	.20	.17
Germany	.41	.29	.22	-.22	.26
Italy	.41	.42	.21	.29	-.16
Japan	.46	.44	.26	.21	.24
UK	.42	.49	.28	.21	.26
USA	.41	.42	.40	-.26	.40
USA	.41	.42	.40	-.26	.40

Note: See Table 1.

Figure 5:  
Comovements

Internationally:



## Stylized Facts

[illegible]

Notes: Statistics are based on Survey of Public Micro data. Variables are:  $y$ , real income;  $x$ , real consumption;  $t$ , and  $\ln(\text{Total Income})$ ;  $g$ , and  $\ln(\text{Government Expenditure})$ ;  $z$ , ratio of net exports to output;  $h$ , ratio of investment to output;  $u$ , inflation rate;  $u_{\text{diff}}$ ,  $\Delta \ln(u)$ ;  $\text{diff}$ ,  $\Delta \ln(y)$ . Source: For the ratio of net exports to output, statistics from the Department of Commerce; for the inflation rate, Bureau of Economic Analysis; for government expenditure, which is less than GPCPI, data from the Bureau of Economic Analysis. The sample period is 1970:1–1992:4.

Figure 4:  
Moments

Country	Correlation with Same U.S. Variable					
	y	a	b	g	h	i
Australia	.21	-.19	.28	.20	-.18	.21
Austria	.38	.33	.46	.20	.47	.17
Canada	.58	.49	-.81	-.50	.50	.73
France	.41	.39	.52	-.10	.26	.39
Germany	.40	.40	.51	.28	.32	.43
Italy	.51	.32	.31	.39	-.31	.33
Japan	.80	.84	.54	.11	.30	.38
Netherlands	.42	.48	.38	.31	.36	.41
United Kingdom	.33	.42	.44	-.26	.40	.31
Europe	.60	.21	.23	.18	.20	.26

Source: See Table 1.

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical
- ▶ trade balance strongly countercyclical
- ▶ positive comovements in output

Internationally:

Figure 5:  
Comoments

## Stylized Facts

[illegible][illegible]

Figure 4:  
Moments

Country	Correlation with Euro U.S. Variable					
	y	a	b	c	d	e
Australia	.21	-.19	.28	.25	-.18	.22
Austria	.34	.33	.46	.20	.47	.17
Canada	.58	.49	-.81	-.54	.50	.73
France	.41	.39	.52	-.10	.36	.39
Germany	.46	.48	.50	.28	.32	.43
Italy	.41	.32	.31	.39	-.35	.33
Japan	.80	.44	.56	.11	.32	.38
Netherlands	.42	.48	.38	.31	.36	.41
United Kingdom	.55	.42	.44	-.56	.40	.31
Europe	.60	.21	.23	.18	.20	.26

Source: See Table 1.

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical
- ▶ trade balance strongly countercyclical
- ▶ positive comovements in output

Internationally:

- ▶ smaller comovements in consumption

Figure 5:  
Comoments

## Stylized Facts

	Ref. Day	Ratio of Baseline Chlorine to Baseline C	Intercept	Correlation with Slope
Chlorine	1	1	1	1
Age	0.04	0.00	0.00	0.00
Female	0.04	0.00	0.00	0.00
Married	0.04	0.00	0.00	0.00
White	0.04	0.00	0.00	0.00
Black	0.04	0.00	0.00	0.00
Hispanic	0.04	0.00	0.00	0.00
Income	0.04	0.00	0.00	0.00
Education	0.04	0.00	0.00	0.00
Population	0.04	0.00	0.00	0.00
Urban	0.04	0.00	0.00	0.00
State	0.04	0.00	0.00	0.00
Year	0.04	0.00	0.00	0.00

[illegible]

Figure 4:  
Moments

Country	Correlation with Euro U.S. Variable					
	y	z	g	h	s	
Australia	.21	-.19	.08	.20	-.18	.22
Austria	.18	.03	.48	.20	.47	.17
Canada	.38	.49	-.81	-.04	.20	.73
France	.41	.39	.32	.30	.36	.39
Germany	.49	.49	.33	.24	.32	.48
Italy	.41	.82	.33	.39	-.81	.25
Japan	.60	.44	.04	.11	.32	.38
Netherlands	.42	.48	.38	.31	.36	.41
United Kingdom	.33	.42	.44	-.26	.49	.32
Europe	.46	.21	.33	.18	.20	.56

Source: See Table 1.

Source: See Table 1.

Figure 5:  
Comoments

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical
- ▶ trade balance strongly countercyclical
- ▶ positive comovements in output

### Internationally:

- ▶ smaller comovements in consumption
  - ▶ Backus-Kehoe-Kydland puzzle

## Stylized Facts

	Rel. Dev. of Expend.	Relative-Deviation of Expend.	Depend.	Correlation Coeff. of Depend.
Country	1	2	3	4
Australia	1.04	1.23	0.150	0.20
Canada	1.00	1.00	0.000	0.00
France	1.00	1.00	0.000	0.00
Germany	1.00	1.00	0.000	0.00
Italy	1.00	1.00	0.000	0.00
Japan	1.00	1.00	0.000	0.00
Spain	1.00	1.00	0.000	0.00
Sweden	1.00	1.00	0.000	0.00
Switzerland	1.00	1.00	0.000	0.00
United Kingdom	1.00	1.00	0.000	0.00
United States	1.00	1.00	0.000	0.00
West Germany	1.00	1.00	0.000	0.00
Yugoslavia	1.00	1.00	0.000	0.00

[illegible]

Figure 4:  
Moments

Country	Correlation with Same U.S. Variable				
	y	c	g	h	s
Australia	.31	-.19	.28	.20	-.18
Austria	.34	.35	.46	.29	.47
Canada	.38	.49	-.81	-.04	.20
France	.41	.39	.32	-.30	.36
Germany	.49	.49	.33	.24	.32
Italy	.41	.32	.31	.39	-.81
Japan	.60	.44	.04	.11	.32
Netherlands	.42	.48	.38	.31	.36
United Kingdom	.53	.42	.46	-.26	.49
Europe	.66	.21	.23	.18	.20

Notes: See Table 1.

Source: See Table 1.

Figure 5:  
Comoments

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical
- ▶ trade balance strongly countercyclical
- ▶ positive comovements in output

## Internationally:

- ▶ smaller comovements in consumption
  - ▶ Backus-Kehoe-Kydland puzzle

# Stylized Facts

Properties of Stylized Facts in 1980 Economy

Country	GDP	Index of Domestic Production					Imports	Productivity with Output				
		1	2	3	4	5		1	2	3	4	5
Canada	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
France	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Germany	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Italy	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Japan	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
UK	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
USA	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Sweden	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Switzerland	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Netherlands	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Belgium	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Australia	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Spain	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Portugal	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Greece	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Ireland	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Iceland	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Luxembourg	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Austria	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Denmark	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Finland	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
South Korea	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
South Africa	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Israel	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Chile	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Argentina	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Brazil	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
India	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
China	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Japan	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
USA	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Sweden	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Switzerland	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Netherlands	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Belgium	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Australia	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Spain	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Portugal	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Greece	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Ireland	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Iceland	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Luxembourg	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Austria	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Denmark	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Finland	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
South Korea	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
South Africa	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Israel	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Chile	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Argentina	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Brazil	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
India	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
China	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Japan	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
USA	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Sweden	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Switzerland	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Netherlands	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Belgium	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Australia	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
Spain	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Portugal	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Greece	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Ireland	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Iceland	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Luxembourg	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Austria	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Denmark	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Finland	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
South Korea	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
South Africa	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Israel	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Chile	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Argentina	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Brazil	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
India	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
China	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Japan	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
USA	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Sweden	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9
Switzerland	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Netherlands	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Belgium	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Australia	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Spain	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Portugal	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Greece	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Ireland	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Iceland	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Luxembourg	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Austria	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Figure 4:  
Moments

Domestically:

- ▶ output more variable than consumption
- ▶ output autocorrelated
- ▶ productivity strongly procyclical
- ▶ trade balance strongly countercyclical
- ▶ positive comovements in output

Internationally:

- ▶ smaller comovements in consumption
- ▶ Backus-Kehoe-Kydland puzzle

Figure 5:  
Comoments

International Comovements in OECD Economies

Country	Correlation with Euro G.D.P. (1980-1990)				
	1	2	3	4	5
Australia	21	-29	28	22	-18
Austria	18	21	20	20	17
Canada	16	46	-26	20	17
France	41	29	22	-22	26
Germany	40	48	28	28	48
Italy	41	32	21	29	-16
Japan	46	44	36	21	24
Netherlands	42	48	38	31	36
United Kingdom	33	42	48	-26	48
Sweden	40	21	21	18	20

Source: See Table 1.

Can we replicate these moments with a BC model?

## Modeling a Small Open Economy

# Endowment model

Representative agents maximizes:

$$\max_{c_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

$$c_t + a_t \leq y_t + (1 + r)a_{t-1}$$

**Endowment economy:**

- ▶ income  $(y_t)_t$  is exogenously given
- ▶ for simplicity we assume it is deterministic

**Small open economy:**

- ▶ *open*: can save  $a_t$  which yields  $a_{t+1}(1 + r)$  in the next period
- ▶ *small*: country takes world interest rate  $r$  as given (no effect on world prices)

We solve this problem with the terminal conditions:

- ▶  $a_{-1}$  given<sup>1</sup>

- ▶  $\lim_{T \rightarrow \infty} a_T \geq 0$

## Endowment model (3)

We get the lagrangian:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t u(c_t) + \sum_{t=0}^{\infty} \beta^t \lambda_t (y_t + (1+r)a_{t-1} - c_t - a_t)$$

First order conditions:

$$u'(c_t) = \lambda_t \quad (1)$$

$$\lambda_t = \beta(1+r)\lambda_{t+1} \quad (2)$$

Under the *technical assumption*  $\beta(1+r) = 1$  we get  $c_t = c_{t+1}$  then

$$c_0 = \frac{r}{1+r} \left\{ (1+r)a_{-1} + \sum_{t=0}^{\infty} \frac{y_t}{(1+r)^t} \right\}$$



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# Current Account

## Reminders on Current Account

The **trade balance** is exports-imports (here  $y_t - c_t$ )

The **current account** is trade balance + net factor payments (here  $y_t - c_t + ra_{t-1}$ )

Positive **current account**: additional lending to the rest of the world.

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The **current account** is trade balance + net factor payments (here  $y_t - c_t + ra_{t-1}$ )

Positive **current account**: additional lending to the rest of the world.

Using the formula from before

$$CA_0 = a_{-1}r + (1 - \frac{r}{1+r})y_0 - \frac{r}{1+r} \left\{ \sum_{t \geq 1}^{\infty} \frac{y_t}{(1+r)^t} \right\}$$

How does the current account reacts to income shocks?

- ▶ current account responds positively to *temporary* shock in income
- ▶ and to news about future income shocks:

## Unit root

Still with the same formula:

$$c_0 = \frac{r}{1+r} \left\{ (1+r)a_{-1} + \sum_{t=0}^{\infty} \frac{y_t}{(1+r)^t} \right\}$$

What is the effect of an increase in  $a_{-1}$ ?

- consumption rises permanently
  - $a_t$  is constant, equal to  $a_{-1}$
  - agent consumes small amount  $r$  corresponding to interest
- this will correspond to a unit root in the solution

## Adding capital

We add capital and production to our endowment economy:

$$y_t = z_t k_{t-1}^\alpha$$

$$k_t = (1 - \delta)k_{t-1} + i_t$$

The aggregate resource constraint becomes:

$$a_t + c_t + i_t = (1 + r)a_{t-1} + y_t$$

Now maximize  $\sum_t \beta^t U(c_t)$

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Now maximize  $\sum_t \beta^t U(c_t)$

We get first order conditions

$$\lambda_t = \beta \lambda_{t+1} (1 + r)$$

$$\lambda_t = \beta \lambda_{t+1} [(1 - \delta) + z_{t+1} f'(k_t)]$$

where  $\lambda_t$  is lagrange multiplier associated to budget constraint.



## Adding capital: optimality conditions

Since  $\lambda_t > 0$  (constraint is always binding), we get:

$$(1 - \delta) + z_{t+1}f'(k_t) = 1 + r$$

$$k_t = \left( \frac{r + \delta}{\alpha z_{t+1}} \right)^{\frac{1}{\alpha-1}}$$

and investment

$$i_t = \left( \frac{r + \delta}{\alpha z_{t+1}} \right)^{\frac{1}{\alpha-1}} - (1 - \delta) \left( \frac{r + \delta}{\alpha z_t} \right)^{\frac{1}{\alpha-1}}$$

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Here investment is fully determined by productivity shocks

► too simple: no international dependence

## Add friction to the investment

A possible solution: change the resource constraint such that adjusting capital is costly

For instance:

$$a_t + c_t + i_t + \frac{\omega (k_t - k_{t-1})^2}{2 k_t} = (1 + r)a_{t-1} + z f(k_{t-1})$$

$$k_t = (1 - \delta)k_{t-1} + i_t$$

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Cf tutorial.

## A benchmark Small Open Economy Model

# A benchmark Small Open Economy Model



Stephanie Schmitt-Grohe and Martin Uribe.

Figure 6: Stephanie Schmitt Grohe and Martin Uribe

*Closing Small Economy Models,*  
Schmitt Grohe and Uribe  
(2003), JIE

- ▶ small open economy model with production, consumption-leisure tradeoff and capital adjustment costs
  - ▶ = RBC+open+adj costs
- ▶ perform some moments matching
- ▶ compare different ways of stationarizing

# The model

$$\max_{c_t, n_t} \sum_{t=0}^{\infty} \beta^t u(c_t, n_t)$$

$$c_t + k_t + a_t = y_t + g_t - \frac{\omega}{2} (k_t - k_{t-1})^2 + (1 - \delta) k_{t-1} + (1 + r^* + \pi(a_{t-1})) a_{t-1}$$

$$y_t = f(k_{t-1}, n_t, z_t)$$

$$z_{t+1} = \rho z_t + \epsilon_{t+1}$$

and

$$u(c, n) = \frac{1}{1 - \sigma} (c^\psi (1 - n)^{1 - \psi})^{1 - \sigma}$$



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The term  $\pi$  is there to make the model stationary.

## How to make the distribution stationary?

The solution of the model exhibits a unit root:

$$a_t = a_{t-1} + \dots \text{other variables in } t-1 + \text{shocks in } t$$

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Problem:

- ▶ there isn't a unique deterministic steady-state
- ▶ the ergodic distribution of the model variables is not defined

This raises practical issues (notably for estimation) for the *linear* model.

- ▶ no unconditional moments

# How to get rid of the unit root?

*General idea:*

- ▶ introduce a force that pulls the level of foreign assets towards equilibrium

Schmitt Grohe and Uribe (2003) consider many options:

- ▶ debt-elastic interest rate:

$$1 + r = 1 + r^* + \pi(a_d)$$

- ▶ with  $\pi(0) = 0$  and  $\pi'(0) > 0$
- ▶  $\pi$  can be understood as a risk premium on rising debt
- ▶ endogenous time-discount (aka Usawa preferences)

$$\beta(c_t) = (1 + c_t)^{-\chi}$$

- ▶ costs of adjustment for international portfolios

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- ▶ costs of adjustment for international portfolios

SGU show that the choice of the stationarization device has little effect for the dynamics (moments) of most variables

# Calibration

Parameters	Values
$\sigma$	2
$\psi$	1.45
$\alpha$	0.32
$\omega$	0.028
$r$	0.04

Parameters	Values
$\delta$	0.1
$\rho$	0.42
$\sigma^2$	0.0129
$A^*$	-0.7442
$\chi$	0.000742

# Results

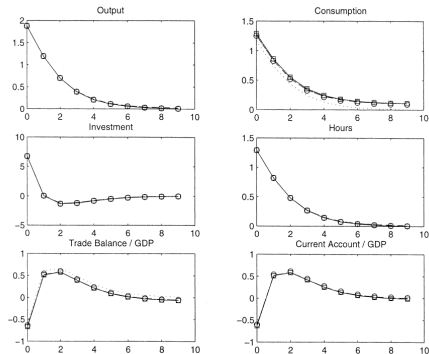


Fig. 1. Impulse response to a unit technology shock in Models 1–5. Note. Solid line: Endogenous discount factor model; Squares: Endogenous discount factor model without internalization; Dashed line: Debt-elastic interest rate model; Dash-dotted line: Portfolio adjustment cost model; Dotted line: complete asset markets model; Circles: Model without stationarity inducing elements.

Figure 7: Impulse Response Function

Table 3  
Observed and implied second moments

	Data	Model 1	Model 1a	Model 2	Model 3	Model 4
<i>Volatilities:</i>						
$\text{std}(y_t)$	2.8	3.1	3.1	3.1	3.1	3.1
$\text{std}(c_t)$	2.5	2.3	2.3	2.7	2.7	1.9
$\text{std}(i_t)$	9.8	9.1	9.1	9	9	9.1
$\text{std}(h_t)$	2	2.1	2.1	2.1	2.1	2.1
$\text{std}\left(\frac{ib_t}{y_t}\right)$	1.9	1.5	1.5	1.8	1.8	1.6
$\text{std}\left(\frac{ca_t}{y_t}\right)$		1.5	1.5	1.5	1.5	
<i>Serial correlations:</i>						
$\text{corr}(y_t, y_{t-1})$	0.61	0.61	0.61	0.62	0.62	0.61
$\text{corr}(c_t, c_{t-1})$	0.7	0.7	0.7	0.78	0.78	0.61
$\text{corr}(i_t, i_{t-1})$	0.31	0.07	0.07	0.069	0.069	0.07
$\text{corr}(h_t, h_{t-1})$	0.54	0.61	0.61	0.62	0.62	0.61
$\text{corr}\left(\frac{ib_t}{y_t}, \frac{ib_{t-1}}{y_{t-1}}\right)$	0.66	0.33	0.32	0.51	0.5	0.39
$\text{corr}\left(\frac{ca_t}{y_t}, \frac{ca_{t-1}}{y_{t-1}}\right)$		0.3	0.3	0.32	0.32	
<i>Correlations with output:</i>						
$\text{corr}(c_t, y_t)$	0.59	0.94	0.94	0.84	0.85	1
$\text{corr}(i_t, y_t)$	0.64	0.66	0.66	0.67	0.67	0.66
$\text{corr}(h_t, y_t)$	0.8	1	1	1	1	1
$\text{corr}\left(\frac{ib_t}{y_t}, y_t\right)$	-0.13	-0.012	-0.013	-0.044	-0.043	0.13
$\text{corr}\left(\frac{ca_t}{y_t}, y_t\right)$		0.026	0.025	0.05	0.051	

Note: The first column was taken from Mendoza (1991). Standard deviations are measured in percent per year.

Figure 8: Moments (from SGU)



# Conclusions

- ▶ The model matches unconditional correlations fairly well
  - ▶ The stationarization device has little effect on the moments
- ▶ Unconditional correlations are not that great
  - ▶ a limitation of the moment matching method?
- ▶ Correlation of consumption with output is too high
  - ▶ and probably cross-correlation of consumption too low
  - ▶ still the Backus-Kehoe-Kydland puzzle...