Interest Rates, Revealed Preferences, and the Open Economy

Adam Gulan

Bank of Finland

National Bank of Poland

July 2019
Test a standard textbook infinite-horizon small open economy (SOE) model by applying the Weak Axiom of Revealed Preference (WARP)

- WARP precludes certain switches in the sign and direction of international accounts variables:
  - a country running initially a positive NX (or NFAP) cannot switch to negative after, ceteribus paribus, an exogenous increase of the interest rate
  - a country running initially a negative NX (or NFAP) cannot switch to positive after, ceteribus paribus, an exogenous decrease of the interest rate
  - the substitution effect has to be negative

(Preliminary!) WARP violations are massive. The model SOE fails to rationalize most switches observed in the data and is clearly rejected.
Question

- Test a standard textbook infinite-horizon small open economy (SOE) model by applying the Weak Axiom of Revealed Preference (WARP)
- WARP precludes certain switches in the sign and direction of international accounts variables:
  - a country running initially a positive NX (or NFAP) cannot switch to negative after, ceteribus paribus, an exogenous increase of the interest rate
  - a country running initially a negative NX (or NFAP) cannot switch to positive after, ceteribus paribus, an exogenous decrease of the interest rate
  - the substitution effect has to be negative
- Preliminary! WARP violations are massive. The model SOE fails to rationalize most switches observed in the data and is clearly rejected.
Test a standard textbook infinite-horizon small open economy (SOE) model by applying the Weak Axiom of Revealed Preference (WARP)

WARP precludes certain switches in the sign and direction of international accounts variables:

- a country running initially a positive NX (or NFAP) cannot switch to negative after, *ceteribus paribus*, an exogenous increase of the interest rate
Question

- Test a standard textbook infinite-horizon small open economy (SOE) model by applying the Weak Axiom of Revealed Preference (WARP)
- WARP precludes certain switches in the sign and direction of international accounts variables:
  - A country running initially a positive NX (or NFAP) cannot switch to negative after, *ceteribus paribus*, an exogenous increase of the interest rate
  - A country running initially a negative NX (or NFAP) cannot switch to positive after, *ceteribus paribus*, an exogenous decrease of the interest rate

Preliminary! WARP violations are massive. The model SOE fails to rationalize most switches observed in the data and is clearly rejected.
Question

- Test a standard textbook infinite-horizon small open economy (SOE) model by applying the Weak Axiom of Revealed Preference (WARP)

- WARP precludes certain switches in the sign and direction of international accounts variables:
  - a country running initially a positive NX (or NFAP) cannot switch to negative after, *ceteribus paribus*, an exogenous increase of the interest rate
  - a country running initially a negative NX (or NFAP) cannot switch to positive after, *ceteribus paribus*, an exogenous decrease of the interest rate
  - the substitution effect has to be negative

Preliminary! WARP violations are massive. The model SOE fails to rationalize most switches observed in the data and is clearly rejected.
Question

- Test a standard textbook infinite-horizon small open economy (SOE) model by applying the Weak Axiom of Revealed Preference (WARP)
- WARP precludes certain switches in the sign and direction of international accounts variables:
  - a country running initially a positive NX (or NFAP) cannot switch to negative after, *ceteribus paribus*, an exogenous increase of the interest rate
  - a country running initially a negative NX (or NFAP) cannot switch to positive after, *ceteribus paribus*, an exogenous decrease of the interest rate
  - the substitution effect has to be negative
- (Preliminary!) WARP violations are massive. The model SOE fails to rationalize most switches observed in the data and is clearly rejected.
Literature review

- tests of the small open economy (SOE) model:
  - other approaches: Glick, Rogoff (JME, 1995) simple regressions, Nason, Rogers (JIE, 2006) Bayesian Monte Carlo

▶ revealed preferences applications to macroeconomics:
- compare international living standards based on PPP: Dowrick, Quiggin (1994, 1997)

▶ revealed preferences and inter-temporal choice:
Echenique et al. (2017), Crawford (2010), Adams et al. (2014)
Literature review

- tests of the small open economy (SOE) model:
  - other approaches: Glick, Rogoff (JME, 1995) simple regressions, Nason, Rogers (JIE, 2006) Bayesian Monte Carlo

- closest: Browning (IER, 1989)
Literature review

- tests of the small open economy (SOE) model:
  - other approaches: Glick, Rogoff (JME, 1995) simple regressions, Nason, Rogers (JIE, 2006) Bayesian Monte Carlo

- closest: Browning (IER, 1989)

- revealed preferences applications to macroeconomics:
  - compare international living standards based on PPP: Dowrick, Quiggin (1994,1997)
Literature review

- tests of the small open economy (SOE) model:
  - other approaches: Glick, Rogoff (JME, 1995) simple regressions, Nason, Rogers (JIE, 2006) Bayesian Monte Carlo

- closest: Browning (IER, 1989)

- revealed preferences applications to macroeconomics:
  - compare international living standards based on PPP: Dowrick, Quiggin (1994, 1997)

Basic idea with 2-period endowment economy

Switches in net exports:

At point $B$ we have $R_1^B + Y_1 - C_1 = B_2 < 0$.

So, following the change, we need $B_2' < 0$ as well.
Basic idea with 2-period endowment economy, cont.

Switches in net foreign asset positions:

At point $\mathbf{C}$ we have $R_1B_1 + Y_1 - C_1 = B_2 < 0$

So, following the change, we need $B'_2 < 0$ as well.
Basic idea with 2-period endowment economy, cont.

Substitution effect:

Following interest rate drop, substitution effect reduces NX/NFAP.
Methodological difficulty
Interpretation of the test

- if there were no changes in inter-temporal wealth \((Y, B)\), we could apply standard revealed preference tests directly on the data (without any models)
- we could then draw conclusions about (aggregate) preferences
Interpretation of the test

▶ if there were no changes in inter-temporal wealth \((Y, B)\), we could apply standard revealed preference tests directly on the data (without any models)
▶ we could then draw conclusions about (aggregate) preferences
▶ the changing nature of inter-temporal wealth makes these tests not directly applicable
▶ we are forced to use a model to remove these effects and to ask counterfactual (what if) questions
▶ any violations can be then be due to misbehavior of preferences or misspecification of the model
Interpretation of the test

- if there were no changes in inter-temporal wealth \((Y, B)\), we could apply standard revealed preference tests directly on the data (without any models)
- we could then draw conclusions about (aggregate) preferences

- the changing nature of inter-temporal wealth makes these tests not directly applicable
- we are forced to use a model to remove these effects and to ask counterfactual (what if) questions
- any violations can be then be due to misbehavior of preferences or misspecification of the model

- assuming that (aggregate) preferences do exist and are well-behaved, we end up testing the SOE model
- alternative interpretation: violations reflect the aggregation of preferences and point to the non-existence of the representative agent
The model

Agents maximize

$$U_t = \sum_{i=0}^{\infty} \beta^i \frac{C_{t+i}^{1-\sigma}}{1-\sigma}$$

subject to the budget constraint

$$C_t + \frac{W_{t+1}}{R} = W_t$$

where beginning-of-period-t wealth $W_t$ is given by

$$W_t = RB_t + Y_t + \frac{Y_{\geq t+1}}{R}$$

and

$$Y_{\geq t+1} = \sum_{i=1}^{\infty} \frac{Y_{t+i}}{R^{i-1}}$$
Consumers’ problem can still be thought of as 2-period, due to Bellman’s formulation:

\[ V(W_t; R) = \max_{C_t} \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} + \beta V(W_{t+1}; R) \right\} \]

subject to

\[ W_{t+1} = R(W_t - C_t) \]

Assumption of constant interest rate \( R \) allows for a closed-form solution for \( V \):

\[ V(R, W_t) = \left[ 1 - \beta \frac{1}{\sigma} R^{\frac{1}{\sigma}} - 1 \right]^{-\sigma} \frac{W_t^{1-\sigma}}{1 - \sigma} \]

which carries over the properties of the utility function (concavity, continuity)
Infinite horizon

\[ W_{t+1} \]

\[ -R \]

\[ Y_{t+1} \]

\[ Y \]

\[ C \]

\[ V = V(R, W_t) \]

\[ RB_t + Y_t \]

\[ C_t \]
Solving the model

- the model consists of 2 equations:
  - Euler, which captures optimal choice between $C_t$ and $W_{t+1}$
  - budget constraint (expenditure on $C_t$ and $W_{t+1}$, given $W_t$)
Solving the model

- the model consists of 2 equations:
  - Euler, which captures optimal choice between $C_t$ and $W_{t+1}$
  - budget constraint (expenditure on $C_t$ and $W_{t+1}$, given $W_t$)

- eliminate $W_{t+1}$ by combining both equations. This gives the Marshallian demand function (consumption $C_t$ as function of wealth $W_t$)
Take first order Taylor expansion of the Marshallian demand function $C_t = f(W_t)$ around ITS FORMER SELF, defining $\hat{C}_{t+1} = \frac{C_{t+1} - C_t}{C_t}$, etc.
Solving the model, cont.

- Take first order Taylor expansion of the Marshallian demand function \( C_t = f(W_t) \) around ITS FORMER SELF, defining \( \hat{C}_{t+1} = \frac{C_{t+1} - C_t}{C_t} \), etc.

- Plug in the demand function \( \hat{C}_{t+1} = g(\hat{W}_{t+1}) \) to (Taylor expansions of) definition of net exports:

\[
\hat{NX}_{t+1} = Y_t \hat{Y}_{t+1} - C_t \hat{C}_{t+1}
\]

where \( \hat{NX}_{t+1} = NX_{t+1} - NX_t \)
Solving the model, cont.

Substituting $\hat{W}_{t+1}$ for its components and rearranging terms gives

$$NX_{t+1} = NX_t - \frac{C_t R_t}{W_t} \hat{B}_{t+1} - \frac{C_t R_t B_t}{W_t} \hat{R}_{t+1}$$

$$- \frac{C_t Y_{\geq t+1}}{W_t} \hat{Y}_{\geq t+2} + \frac{Y_t (W_t - C_t)}{W_t} \hat{Y}_{t+1}$$

$$- \left\{ \begin{array}{l}
\frac{-C_t (W_t - C_t)}{W_t} \frac{1}{\sigma} + \frac{C_t (W_t - C_t)}{W_t} - \frac{C_t Y_{\geq t+1}}{W_t} + \frac{(W_t - C_t)^2}{W_t} \left(1 - \frac{1}{\sigma}\right) \\
\text{Substitution effect} \quad \text{Income effect} \quad \text{Wealth effect} \quad \text{value function effect}
\end{array} \right\} \hat{R}_{t+2}$$

where $\hat{R}_{t+2} = \frac{R_{t+2} - R_{t+1}}{R_{t+1}}$

$R_{t+1}$ is the permanent $R$ before the change ("MIT shock")

$R_{t+2}$ is the new permanent $R$ after the MIT shock
Testing

Construct "what if" variables $\overline{NX}_{t+1}$, $\overline{B}_{t+2}$ and $\overline{B}_{t+2}^{SUB}$ which remove the undesired impact of changes in wealth from their empirical counterparts.

- **Test 1**: Suppose $NX_t < 0$, $NX_{t+1} > 0$ and $R_{t+2} < R_{t+1}$. WARP is violated if $\overline{NX}_{t+1} > 0$.

- **Test 2**: Suppose $NX_t > 0$, $NX_{t+1} < 0$ and $R_{t+2} > R_{t+1}$. WARP is violated if $\overline{NX}_{t+1} < 0$.

- **Test 3**: Suppose $B_{t+1} < 0$, $B_{t+2} > 0$ and $R_{t+2} < R_{t+1}$. WARP is violated if $\overline{B}_{t+2} > 0$.

- **Test 4**: Suppose $B_{t+1} > 0$, $B_{t+2} < 0$ and $R_{t+2} > R_{t+1}$. WARP is violated if $\overline{B}_{t+2} < 0$.

- **Test 5**: Suppose $R_{t+2} < R_{t+1}$. WARP is violated if $\overline{B}_{t+2}^{SUB} > 0$.

- **Test 6**: Suppose $R_{t+2} > R_{t+1}$. WARP is violated if $\overline{B}_{t+2}^{SUB} < 0$. 
Testing

Construct "what if" variables $\overline{NX}_{t+1}, \overline{B}_{t+2}$ and $\overline{B}^{SUB}_{t+2}$ which remove the undesired impact of changes in wealth from their empirical counterparts.

- **Test 1**: Suppose $NX_t < 0$, $NX_{t+1} > 0$ and $R_{t+2} < R_{t+1}$. WARP is violated if $\overline{NX}_{t+1} > 0$.

- **Test 2**: Suppose $NX_t > 0$, $NX_{t+1} < 0$ and $R_{t+2} > R_{t+1}$. WARP is violated if $\overline{NX}_{t+1} < 0$. 
Testing

Construct "what if" variables $\overline{NX}_{t+1}$, $\overline{B}_{t+2}$ and $\overline{B}^{SUB}_{t+2}$ which remove the undesired impact of changes in wealth from their empirical counterparts.

▶ Test 3: Suppose $B_{t+1} < 0$, $B_{t+2} > 0$ and $R_{t+2} < R_{t+1}$. WARP is violated if $\overline{B}_{t+2} > 0$. 
Testing

Construct "what if" variables $\bar{NX}_{t+1}$, $\bar{B}_{t+2}$ and $\bar{B}_{t+2}^{ SUB }$ which remove the undesired impact of changes in wealth from their empirical counterparts.

- **Test 3**: Suppose $B_{t+1} < 0$, $B_{t+2} > 0$ and $R_{t+2} < R_{t+1}$. WARP is violated if $\bar{B}_{t+2} > 0$.
- **Test 4**: Suppose $B_{t+1} > 0$, $B_{t+2} < 0$ and $R_{t+2} > R_{t+1}$. WARP is violated if $\bar{B}_{t+2} < 0$. 
Testing

Construct "what if" variables $\bar{NX}_{t+1}$, $\bar{B}_{t+2}$ and $\bar{B}^{SUB}_{t+2}$ which remove the undesired impact of changes in wealth from their empirical counterparts.

- **Test 5**: Suppose $R_{t+2} < R_{t+1}$. WARP is violated if $\bar{B}^{SUB}_{t+2} > 0$. 
Testing

Construct "what if" variables $\overline{NX}_{t+1}$, $\overline{B}_{t+2}$ and $\overline{B}^{SUB}_{t+2}$ which remove the undesired impact of changes in wealth from their empirical counterparts.

- **Test 5**: Suppose $R_{t+2} < R_{t+1}$. WARP is violated if $\overline{B}^{SUB}_{t+2} > 0$.
- **Test 6**: Suppose $R_{t+2} > R_{t+1}$. WARP is violated if $\overline{B}^{SUB}_{t+2} < 0$. 
Data

- Annual (1970-2016) panel of 20 developed countries
- National accounts data (Eurostat, IFS, national statistical offices) for $Y$ and $C$
- Lane and Milesi-Ferretti’s External Wealth of Nations Mark II Database for $B$
- all variables are per capita, in real national currency
- $Y$ is GDP less public consumption and investment ($C$ is private consumption)
- GDP beyond 2016 is proxied by running an AR(1) regression (with constant and deterministic trend) on in-sample data
- World interest rate is (deflated) U.S. BAA corporate bonds
Switches from surplus to deficit

| Year | AUS | AUT | BEL | CAN | DEN | FIN | FRA | GER | GRE | ICE | ITA | JAP | NEL | NEW | NOR | POR | SPA | SWE | SWI | UK | Violations |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|-------------|
| 1972 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1972         |
| 1973 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1973         |
| 1974 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 1975         |
| 1975 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1976         |
| 1976 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1977         |
| 1977 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1978         |
| 1978 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1979         |
| 1979 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1980         |
| 1980 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 1981         |
| 1981 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 1982         |
| 1982 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1983         |
| 1983 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1984         |
| 1984 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 2 | 1985         |
| 1985 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1986         |
| 1986 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1987         |
| 1987 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 1988         |
| 1988 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1989         |
| 1989 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1990         |
| 1990 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 1991         |
| 1991 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1992         |
| 1992 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1993         |
| 1993 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1994         |
| 1994 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1995         |
| 1995 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1996         |
| 1996 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1997         |
| 1997 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1998         |
| 1998 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 1999         |
| 1999 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2000         |
| 2000 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2001         |
| 2001 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2002         |
| 2002 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2003         |
| 2003 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2004         |
| 2004 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2005         |
| 2005 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2006         |
| 2006 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 2007         |
| 2007 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2008         |
| 2008 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 1 | 2009         |
| 2009 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2010         |
| 2010 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2011         |
| 2011 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2012         |
| 2012 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2013         |
| 2013 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2014         |
| 2014 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 0 | 2015         |

Violations: 0 1 2 0 1 0 1 0 2 1 0 0 1 0 0 0 1 0 0
Switches from deficit to surplus

| Year | AUS | AUT | BEL | CAN | DEN | FIN | FRA | GER | GRE | ICE | ITA | JAP | NET | NEW | NOR | POR | SPA | SWE | SWI | UK | Violations |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|---------------|
| 1972 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 2            |
| 1973 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1974 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1975 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1976 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 2            |
| 1977 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 3            |
| 1978 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 6            |
| 1979 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 1            |
| 1980 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1981 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1982 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1983 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1984 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1985 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1986 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1987 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1988 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1989 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1990 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1991 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1992 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1993 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1994 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1995 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1996 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1997 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1998 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 1999 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2000 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2001 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2002 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2003 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2004 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2005 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2006 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2007 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2008 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2009 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2010 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2011 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2012 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2013 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2014 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
| 2015 |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    | 0            |
Switches from creditor to debtor
Substitution effect with increasing R
Substitution effect with decreasing R
Robustness and follow-up work

- production economy not likely to help
  - more structure is more potential for misspecification
Robustness and follow-up work

- production economy not likely to help
  - more structure is more potential for misspecification

- empirical measures of:
  - world interest rate and discounting
  - inter-temporal wealth
Robustness and follow-up work

- production economy not likely to help
  - more structure is more potential for misspecification
- empirical measures of:
  - world interest rate and discounting
  - inter-temporal wealth
- time-varying interest rate
Robustness and follow-up work

- production economy not likely to help
  - more structure is more potential for misspecification
- empirical measures of:
  - world interest rate and discounting
  - inter-temporal wealth
- time-varying interest rate
- how "bad" are the violations
  - Afriat/Varian efficiency index
  - Echenique money pump index
Robustness and follow-up work

- production economy not likely to help
  - more structure is more potential for misspecification
- empirical measures of:
  - world interest rate and discounting
  - inter-temporal wealth
- time-varying interest rate
- how "bad" are the violations
  - Afriat/Varian efficiency index
  - Echenique money pump index
- uncertainty
  - it’s another margin along which agents may violate