Policy Applications of Econometric Models

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Econometric Model

(1) structural form:

$$\underset{1\times g}{\mathbf{y}_t}\ \underset{g\times g}{\mathbf{\Gamma}} + \underset{1\times g}{\mathbf{y}_{t-1}}\ \underset{g\times g}{\mathbf{B}_1} + \underset{1\times k}{\mathbf{z}_t}\ \underset{k\times g}{\mathbf{B}_2} + \underset{1\times l}{\mathbf{r}_{t-1}}\ \underset{l\times g}{\mathbf{A}} = \underset{1\times g}{\boldsymbol{\varepsilon}_t}, \qquad t = 1,2,\ldots,T$$

$\mathbf{y}_t$ endogenous variables (g) (targets or irrelevant)

$\mathbf{y}_{t-1}$ lagged endogenous variables (g)

$\mathbf{z}_t$ exogenous variables (non-controlled) (k)

$\mathbf{r}_{t-1}$ (or $\mathbf{r}_t$) control (instrument, policy) variables (l)

Econometric Model

(2) reduced form:

if Γ nonsingular:

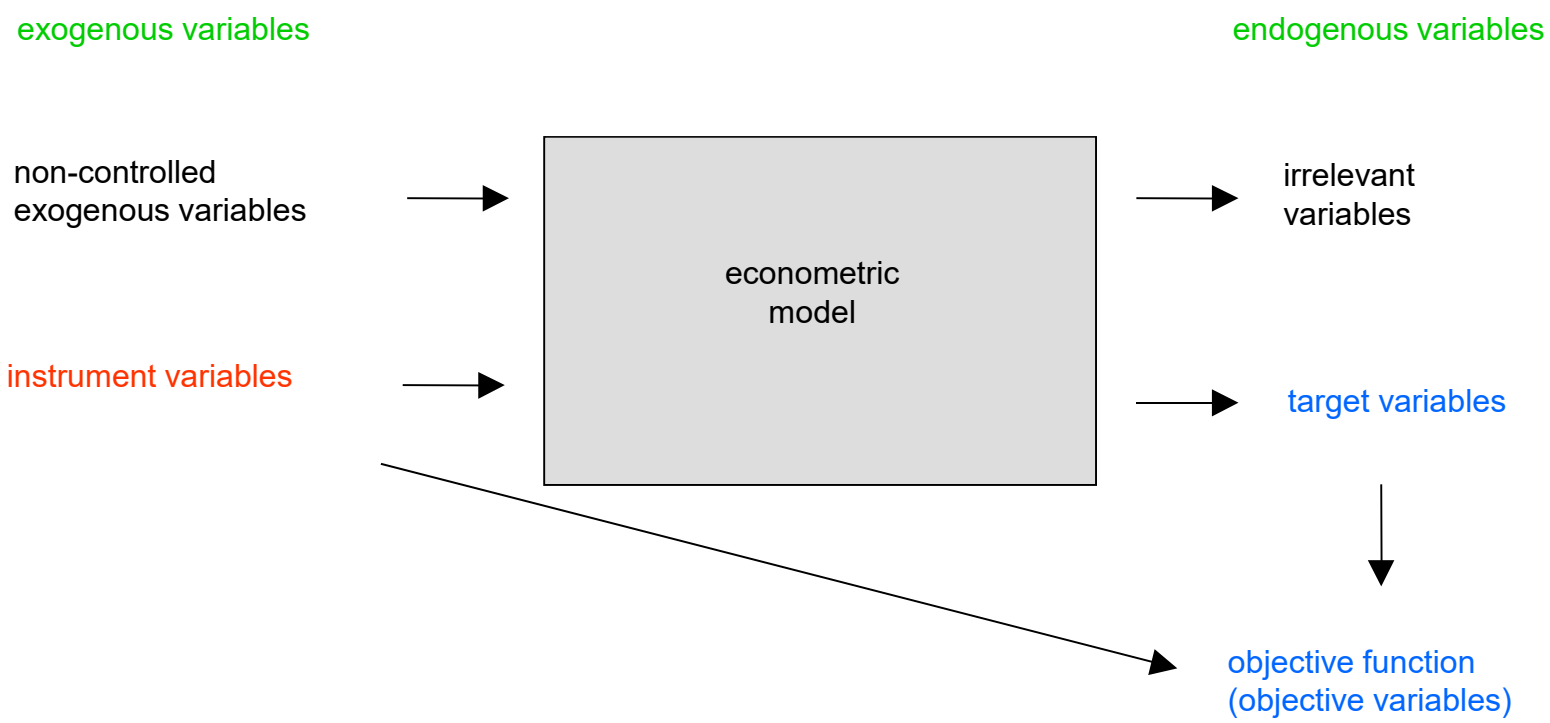
$$\mathbf{y}_t = -\mathbf{y}_{t-1}\mathbf{B}_1\Gamma^{-1} - \mathbf{z}_t\mathbf{B}_2\Gamma^{-1} - \mathbf{r}_{t-1}\mathbf{A}\Gamma^{-1} + \boldsymbol{\varepsilon}_t\Gamma^{-1}$$

(3) final form:

estimates: $\hat{\Gamma}$, $\hat{\mathbf{B}}_1$, $\hat{\mathbf{B}}_2$, $\hat{\mathbf{A}}$

Policy problems

"taxonomic approach"



Policy problems

(1) fixed targets (instrument-targets approach)

Tinbergen 1952

desired targets $\mathbf{y}_{T+1}^{0}$

find $\mathbf{r}_{T}^{*}$ such that:

$$\mathbf{r}_{T}^{*} = -\mathbf{y}_{T+1}^{0}\hat{\mathbf{\Gamma}}\hat{\mathbf{A}}^{-1} - \mathbf{y}_{T}\hat{\mathbf{B}}_{1}\hat{\mathbf{A}}^{-1} - \hat{\mathbf{z}}_{T+1}\hat{\mathbf{B}}_{2}\hat{\mathbf{A}}^{-1} + \hat{\boldsymbol{\varepsilon}}_{T+1}\hat{\mathbf{A}}^{-1} \qquad \left(\text{if } \exists\, \hat{\mathbf{A}}^{-1}\right)$$

Policy problems

(2) flexible targets (optimization, “social welfare (loss, objective) function”, optimal control, etc.)

$$W = W\left(\mathbf{y}_{T+1}, \mathbf{r}_T\right)$$

e.g. $$W = -\frac{1}{2}\left(\mathbf{y}_{T+1} - \mathbf{y}_{T+1}^0\right)\mathbf{E}\left(\mathbf{y}_{T+1} - \mathbf{y}_{T+1}^0\right)' - \frac{1}{2}\left(\mathbf{r}_T - \mathbf{r}_T^0\right)\mathbf{F}\left(\mathbf{r}_T - \mathbf{r}_T^0\right)'$$

$\mathbf{y}_{T+1}^0$ $\mathbf{r}_T^0$ desired values

$\mathbf{E}$, $\mathbf{F}$ weights

Policy problems

problem:

$$\max_{\mathbf{r}_T} W\left(\mathbf{y}_{T+1}, \mathbf{r}_T\right) \quad \text{subject to} \quad \mathbf{y}_{T+1}\hat{\Gamma} + \mathbf{y}_T\hat{\mathbf{B}}_1 + \hat{\mathbf{z}}_{T+1}\hat{\mathbf{B}}_2 + \mathbf{r}_T\hat{\mathbf{A}} = \hat{\boldsymbol{\varepsilon}}_{T+1}$$

solution:

linear decision rule

$$\mathbf{r}_T^* = \mathbf{r}_T^0 + \left(\mathbf{y}_{T+1} - \mathbf{y}_{T+1}^0\right)\mathbf{E}\left(\hat{\Gamma}'\right)^{-1}\hat{\mathbf{A}}'\mathbf{F}^{-1}$$

Policy problems

(3) simulation:

alternative policy options

$$\mathbf{y}_{T+1} = -\mathbf{r}_T \hat{\mathbf{A}}\hat{\Gamma}^{-1} - \mathbf{y}_T \hat{\mathbf{B}}_1 \hat{\Gamma}^{-1} - \hat{\mathbf{z}}_{T+1} \hat{\mathbf{B}}_2 \hat{\Gamma}^{-1} + \hat{\boldsymbol{\varepsilon}}_{T+1} \hat{\Gamma}^{-1}$$

policy multipliers:

$$\frac{\partial \mathbf{y}_{T+1}}{\partial \mathbf{r}_T} = -\hat{\mathbf{A}}\hat{\Gamma}^{-1}$$

Application: an econometric policy model for Slovenia

- SLOPOL4 model
- A policy simulation: access to the Euro Area
- Optimal policies for Slovenia
  - Outline of the optimization exercises
  - Results
- Sensitivity analyses
  - Optimization layout
  - Stochastic parameters
- Concluding remarks

SMEEM

- Original model SMEEM
  - Weyerstrass, Haber, Neck (2000)
  - Slovenian Macro Economic Energy Model (project)
- Combination of
  - Macroeconomic model
  - Energy system model

SLOPOL 4

- Structural model (Version: SLOPOL 4)
- Behavioral equations for several markets
  - Goods
  - Labor
  - Foreign Exchange
  - Money
- Wage and price rigidities, persistent disequilibria possible
- Estimation: OLS

Data Basis

- Quarterly data
  - 1992:1 – 2003:4, updated to 2005
  - Institute for Macroeconomic Analyses and Development (IMAD)
  - Bank of Slovenia
- Short and unreliable time series
- Structural break in 1991
- Transformation crisis and catching-up

Model equations

Behavioral Equations

R^2 is the adjusted coefficient of determination, DW is the Durbin Watson statistic;

t-statistics are given in parentheses below coefficients.

Potential output

$$\log(YPOT) = -0.839136 + 0.6481 * \log(TREND\_EMP) + (1 - 0.6481) * \log(CAPR) + 0.0044 * \text{TIME}$$

$$\log(GDPR) = \underset{(-2.548920)}{-0.839136} + \underset{(3.625960)}{0.6481} * \log(EMP) + \underset{(3.625960)}{(1 - 0.6481)} * \log(CAPR) + \underset{(3.339869)}{0.0044} * TIME$$

$R^2 = 0.986289$ DW = 0.801470

NAIRU

$$D(NAIRU) = \underset{(-1.124953)}{-0.044581} - \underset{(-1.856249)}{0.283872} * D(NAIRU(-1)) + \underset{(2.335843)}{0.387325} * D(NAIRU(-3))$$

$$+ \underset{(1.845909)}{0.281913} * D(NAIRU(-4)) + \underset{(3.380917)}{0.496290} * D(NAIRU(-5)) - \underset{(-1.814794)}{0.276744} * D(NAIRU(-8))$$

$R^2 = 0.395800$ DW = 2.376885

Model equations

Consumption of private households

$$\log(CR/CR(-1)) = \underset{(1.841513)}{0.413191} + \underset{(4.390582)}{0.375626} * \log(INCOMER / INCOMER(-1)) - \underset{(-3.586244)}{0.294} * \log(CR(-1))$$

$$+ \underset{(2.575871)}{0.199217} * \log(INCOMER(-1)) \underset{(-2.415892)}{-0.002379} * ILONGR(-1) + \underset{(4.291727)}{0.0321} * DUM992$$

$$- \underset{(-4.896282)}{0.041086} * DUM993$$

$R^2 = 0.825881$ DW = 2.262197

Gross fixed capital formation

$$\log(PRINVR / PRINVR(-4)) = \underset{(0.572847)}{0.547377} + \underset{(5.306386)}{1.677160} * \log(DEMAND / DEMAND(-4))$$

$$\underset{(-4.372626)}{-0.5822} * \log(PRINVR(-4)) + \underset{(2.114335)}{0.3859} * \log(DEMAND(-4)) - \underset{(-2.100554)}{0.1335} * \log(UCC(-4))$$

$R^2 = 0.781110$ DW = 0.960741

Model equations

Inventory investment

$$INVENTR = 6.756782 + 0.613727 * INVENTR(-1) - 0.531997 * D(GDPR-INVENTR)$$
$$(4.902811)\ \ (4.301567) \qquad\qquad (-4.923027)$$

$R^2 = 0.416334$ DW = 2.424885

Exports of goods and services

$$\log\left(EXR / EXR(-4)\right) = -0.028018 + 0.258837 * \log(EXR(-1) / EXR(-5))$$
$$(-2.582361)\ \ (2.937710)$$

$$+ 0.986657\ * \log\left(GDPEUR12 / GDPEUR12(-4)\right)$$
$$(3.044261)$$

$$+ 0.528579 * \log(SITEURREAL(-4) / SITEURREAL(-8))$$
$$(2.534204)$$

$$-0.908508 * (\log(EXR(-4)) - 0.4716 * \log(GDPEUR12(-4))$$
$$(-5.685921)$$

$$- 0.4328 * \log(SITEURREAL(-4)) - 0.01558 * TIME + 0.023221 * DUM05$$
$$(2.142191)$$

$R^2 = 0.842509$ DW = 1.820122

Model equations

Imports of goods and services

$$\log(IMPR / IMPR(-1)) = -1.743142 + 1.882760 * \log(DEMAND / DEMAND(-1))$$
$$(-4.490866)\ (28.51655)$$

$$- 0.447201 * \log(IMPR(-1)) + 0.631109 * \log(DEMAND(-1))$$
$$(-4.281792)\qquad (4.363494)$$

$R^2 = 0.967468$ DW = 2.029496

Employment

$$\log(EMP / EMP(-4)) = 2.000938 + 0.339420 * \log(EMP(-2) / EMP(-6))$$
$$(1.592327)\ \ (2.785268)$$

$$+ 0.271201 * \log(GDPR / GDPR(-4)) \ - 0.652660 * \log(EMP(-4))$$
$$(2.200591)\qquad (-3.686853)$$

$$+ 0.386212 * \log(GDPR(-4)) - 0.122940 * \log(ULC(-4))$$
$$(5.041517)\qquad (-2.556979)$$

$R^2 = 0.796073$ DW = 1.066295

Model equations

Labour supply

$$\log(LFORCE / LFORCE(-4)) = 5.855133 + 0.608731 * \log(LFORCE(-1) / LFORCE(-5))$$
$$(7.074960)\ (9.178539)$$

$$+ 0.164755 * \log(NETWAGER / NETWAGER(-4))$$
$$(6.561016)$$

$$+ 0.123446 * \log(GDPR(-1) / GDPR(-5))$$
$$(1.987059)$$

$$- 0.965166 * \log(LFORCE(-4)) + 0.112916 * \log(NETWAGER(-4))$$
$$(-7.360987) \qquad (7.946351)$$

$R^2 = 0.916719$ DW = 1.879502

Model equations

Wage rate

$$\log(AGWN / AGWN(-4)) = -0.066109 + 0.432615 * \log(AGWN(-1) / AGWN(-5))$$
$$(-0.177182) \quad (4.616714)$$

$$-0.554777 * \log((AGWN(-4) / CPI(-4))) + 0.249325 * \log(PROD(-4))$$
$$(-5.577310) \qquad\qquad (2.522555)$$

$$-0.007189 * UR(-1) + 0.074054 * \log(WEDGE(-1) / WEDGE(-5))$$
$$(-2.521480) \qquad (1.878302)$$

$$+ 0.446809 * \log(CPI / CPI(-4))$$
$$(3.392647)$$

$R^2 = 0.943467$ DW = 1.615415

Model equations

Consumer price index

$$\log(CPI / CPI(-4)) = -0.74292 + 0.33269 * \log(CPI(-1) / CPI(-5)) + 0.15629 * \log(ULC / ULC(-4))$$
$$(-2.3881) \quad (3.7051) \quad (2.9886)$$

$$+ 0.308681 * \log(SITEUR / SITEUR(-4)) - 0.342909 * \log(CPI(-4))$$
$$(5.461068) \quad (-4.365554)$$

$$+ 0.344927 * \log(ULC(-4)) + 0.374697 * \log(UTIL(-4))$$
$$(4.145779) \quad (5.364040)$$

$R^2 = 0.961850$ $\quad$ DW = 1.707717

Model equations

GDP deflator

$$\log(GDPDEF / GDPDEF(-4)) = 0.120166 + 0.516409 * \log(GDPDEF(-1) / GDPDEF(-5))$$
$$(2.563534) \quad (5.377703)$$

$$+ 0.734706 * \log(CPI / CPI(-4))$$
$$(5.851895)$$

$$- 0.361865 * \log(GDPDEF(-4) / CPI(-4))$$
$$(-2.836337)$$

$R^2 = 0.844573$ DW = 1.606334

Model equations

Real money demand

$$\log(M3R / M3R(-4)) = -2.214662 + 0.538002 * \log(M3R(-1) / M3R(-5))$$
$$(-2.546158) \quad (4.537744)$$

$$- 0.405264 * \log(M3R(-4)) + 0.820429 * \log(GDPR(-4))$$
$$(-3.516973) \quad (3.132024)$$

$$- 0.031762 * (STIRLN / STIRLN(-4))$$
$$(-1.408705)$$

$R^2 = 0.721868$ DW = 1.969595

Long-term interest rate

$$(LTIRLN - LTIRLN(-4)) = 1.006125 * (STIRLN - STIRLN(-4)) + 0.419646 * (EUR10Y - EUR10Y(-4))$$
$$(26.49522) \quad (2.035559)$$

$$- 0.539421 * LTIRLN(-4) + 0.597430 * STIRLN(-4)$$
$$(-3.248753) \quad (3.227697)$$

$R^2 = 0.963106$ DW = 0.538018

Model equations

Short-term interest rate

$$(STIRLN - STIRLN(-4)) = 1.292312 * INFL + 0.418398 * (GRGDPR - GRYPOT)$$
$$(10.55622) \qquad (2.220118)$$

$$- \ 0.905898 * (STIRLN(-4) - EUR3M(-4))$$
$$(-11.96319)$$

$R^2 = 0.797275$ DW = 0.684259

Exchange rate

$$(SITEUR / 100) = 0.212657 - 0.001893 * (LTIRLN - EUR10Y) + 1.672422 * (CPI / HICPEUR12)$$
$$(5.460691) \ (-2.027690) \qquad (61.08336)$$

$R^2 = 0.996093$ DW = 0.895409

Model equations

Social security contributions by companies

$$\log(SOCCOMP / SOCCOMP(-4)) = -0.527861 + 0.538986 * \log(SOCEMP / SOCEMP(-4))$$
$$(-6.497854) \quad (6.649808)$$

$$- 0.547033 * \log(SOCCOMP(-4)) + 0.620918 * \log(SOCEMP(-4))$$
$$(-10.49479) \quad (13.81405)$$

$$+ 0.245643 * DUM05$$
$$(14.53665)$$

$R^2 = 0.941112$ DW = 1.823315

Corporate taxes

$$\log(INCCORP / INCCORP(-4)) = -7.144794 + 0.169314 * \log(INCCORP(-1) / INCCORP(-5))$$
$$(-6.187364) \quad (2.102092)$$

$$- 0.747633 * \log(INCCORP(-4)) + 1.331591 * \log(GDPN(-4))$$
$$(-8.024657) \quad (6.701796)$$

$$- 0.654201 * DUM992$$
$$(-6.812059)$$

$R^2 = 0.808315$ DW = 1.744074

Model equations

Balance of other government revenues and expenditures

$$\log(BUDGETREST / BUDGETREST(-4)) = -0.501472 + 1.031814 * \log(DEBT / DEBT(-4))$$
$$(-0.940508) \quad (2.476841)$$

$$- 0.934227 * \log(BUDGETREST(-4))$$
$$(-7.272604)$$

$$+ 0.783257 * \log(DEBT(-4)) - 0.413477 * DUM021$$
$$(5.762485) \qquad (-4.426783)$$

$R^2 = 0.715886$ DW = 2.032736

Interest payments on government debt

$$(INTEREST - INTEREST(-1)) = -7.689128 - 1.049878 * (INTEREST(-1)) + 0.018931 * (DEBT(-1))$$
$$(-1.948023) \quad (-6.077313) \qquad (5.341489)$$

$$+ 0.292619 * LTIRLN(-1)$$
$$(2.178987)$$

$R^2 = 0.507888$ DW = 1.949515

Model equations

Government consumption according to financial account

$$\log(GNFIN / GNFIN(-4)) = 0.053910 + 1.145092 * \log(GN / GN(-4) - 0.612290 * \log(GNFIN(-4))$$
$$(0.423991)\ (5.166543) \qquad (-3.868434)$$

$$+ 0.583018 * \log(GN(-4))$$
$$(3.649542)$$

$R^2 = 0.713945$ DW = 1.470469

Short-term interest rate in model version with fixed exchange rates

$$(STIRLN - STIRLN(-4)) = 1.319104 + 0.998259 * (EUR3M - EUR3M(-4))$$
$$(1.360326)\ (2.901757)$$

$$+ 0.523320 * (SITEUR - SITEUR(-4)) - 0.587592 * (STIRLN(-4) - EUR3M(-4))$$
$$(7.518843) \qquad (-7.106245)$$

$R^2 = 0.748326$ DW = 0.960985

Model equations

Identities

*GR = GN / GDPDEF * 100*
*AGWR = AGWN / CPI * 100*
*CAN = EXR * GDPDEF / 100 – IMPR * GDPDEF / 100*
*CAGDP = CAN / GDPN * 100*
ILONGR = LTIRLN – INFL
*GRGDPR = GDPR / GDPR(–4) * 100 – 100*
*GRYPOT = (YPOT / YPOT(–4) – 1) * 100*
*PROD = GDPR / EMP * 100*
ULC = AGWN / PROD
UN = LFORCE – EMP
*UR = UN / LFORCE * 100*
DEMAND = INVR + INVENTR + CR + GR + EXR
*M3N = M3R * CPI / 100*
*SITEURREAL = SITEUR * HICPEUR12 / CPI*
INCOME = GDPN + TRANSFERSN – INCTAX – SOCTOTAL
*INCOMER = INCOME / CPI * 100*
*INFL = (CPI / CPI(–4) – 1) * 100*
UCC = ILONGR + 2.7

Model equations

$$
\begin{aligned}
PERSINCTAX &= INCTAXRATE * (AGWN * EMP / 1000) / 100 \\
SOCEMP &= SOCEMPRATE * (AGWN * EMP / 1000) / 100 \\
WEDGE &= AGWN * (INCTAXRATE / 100 + SOCEMPRATE / 100) \\
NETWAGEN &= AGWN - WEDGE \\
NETWAGER &= NETWAGEN / CPI * 100 \\
SOCTOTAL &= SOCCOMP + SOCEMP \\
INCTAX &= PERSINCTAX + INCCORP \\
CAPR &= (1 - DEPR / 100) * CAPR(-1) + INVR \\
GDPR &= CR + GR + INVR + INVENTR + EXR - IMPR \\
GDPN &= GDPR * GDPDEF / 100 \\
TREND\_EMP &= LFORCE * (1 - NAIRU / 100) \\
UTIL &= GDPR / YPOT * 100 \\
DEFICITN &= GNFIN + GINVN + TRANSFERSN + INTEREST - SOCTOTAL \\
&\quad - INCTAX - BUDGETREST \\
DEFGDP &= DEFICITN / GDPN * 100 \\
DEBT &= DEBT(-1) + DEFICITN + DEBTADJ \\
DEBTGDP &= DEBT / (GDPN + GDPN(-1) + GDPN(-2) + GDPN(-3)) * 100 \\
GINVR &= GINVN / GDPDEF * 100 \\
INVR &= PRINVR + GINVR
\end{aligned}
$$

Simulation design

- Simulations of SLOPOL
- Simulation period: 2006 to 2010
- Effects of euro area integration:
  - Abandoning of independent monetary policy
  - Permanent shift of TFP *level* by 1.5 percent
- 4 simulations:
  - Baseline (no Euro Area accession)
  - Isolated effects of common monetary policy
  - Isolated effects of total factor productivity (TFP) shift
  - Overall macroeconomic effects of euro area accession

Simulation design

Abandoning of independent monetary policy:

Simulations with flexible and with fixed exchange rates

TFP level shift:

Cobb-Douglas production function:

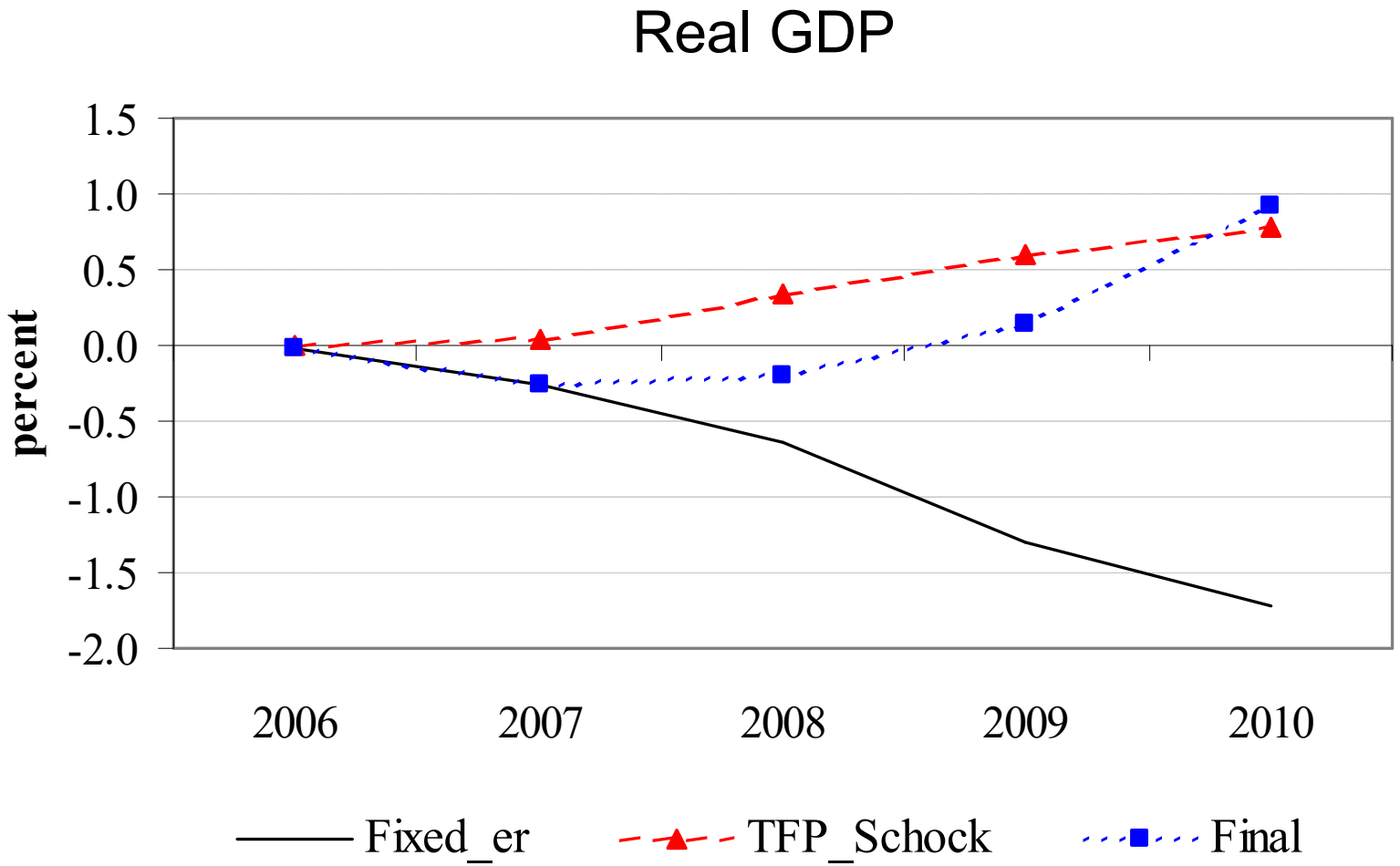
$\log(YPOT) = -0.839 + 0.648 \log(TREND\_EMP) + (1 - 0.648) \log(CAPR) + 0.0044\ TIME$

YPOT: Potential GDP, *TREND_EMP*: Trend employment, *CAPR*: capital stock,

TIME: linear time trend

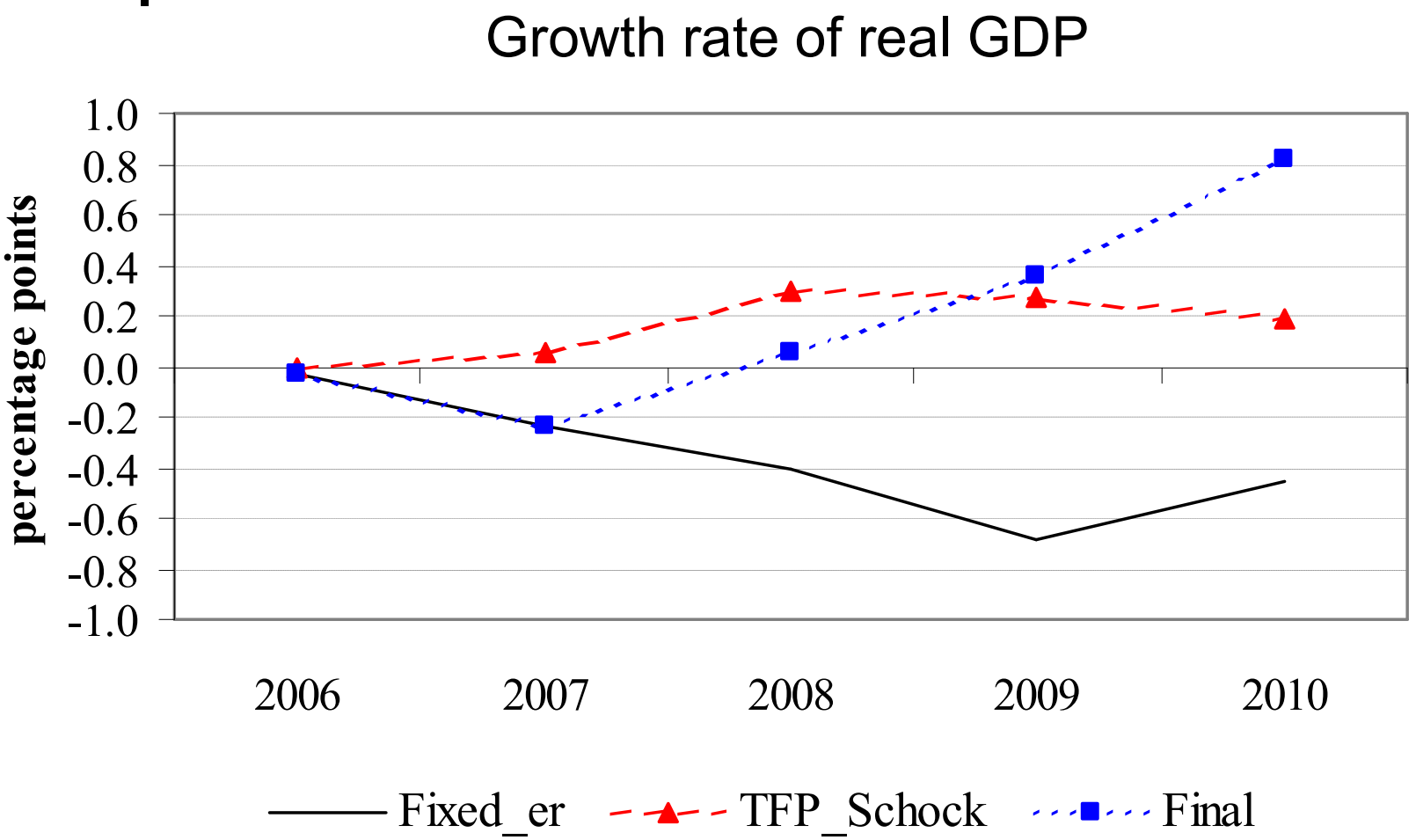
In simulations: exogenous increase of shift parameter (constant)

Simulation results



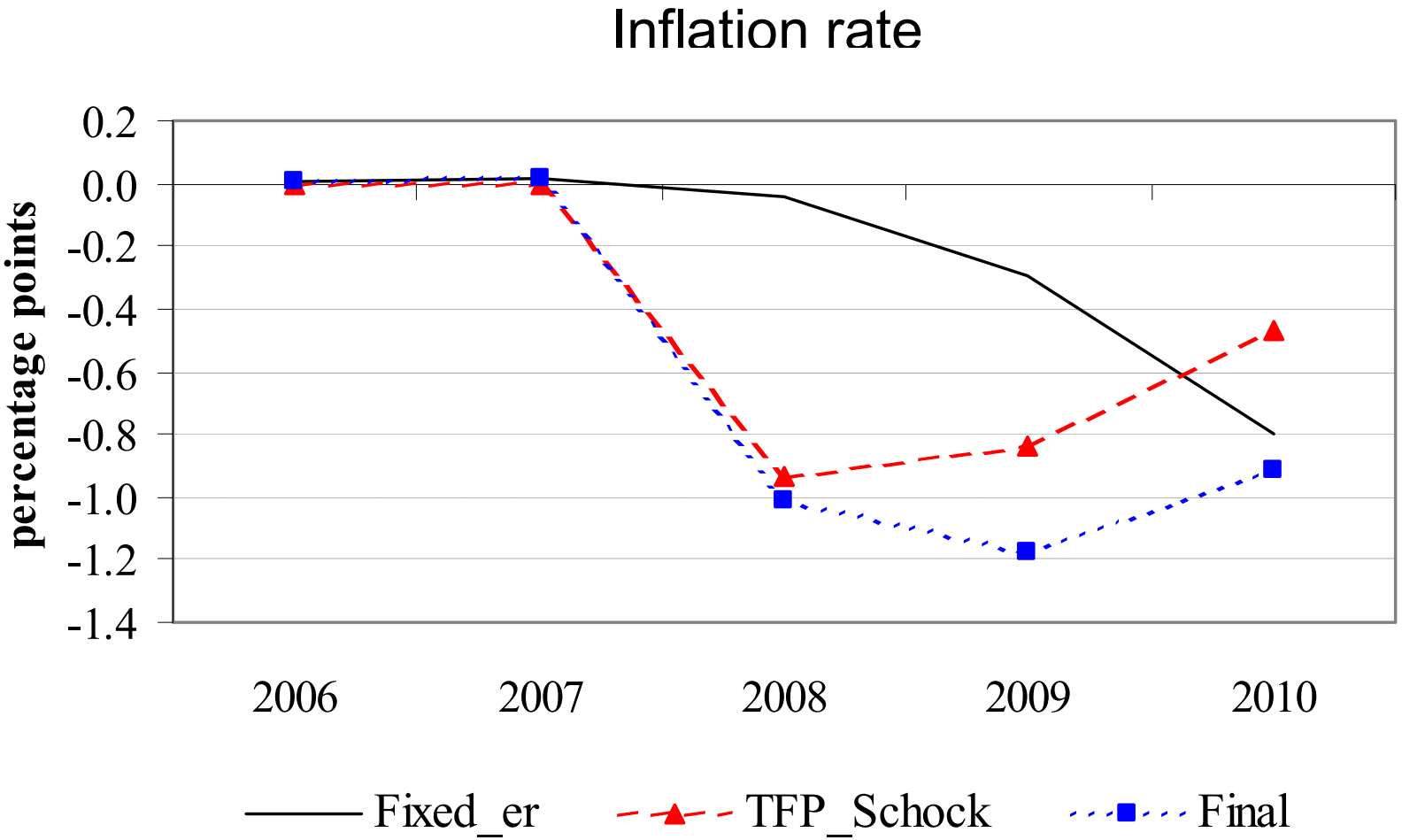
Deviations from baseline in percent

Simulation results



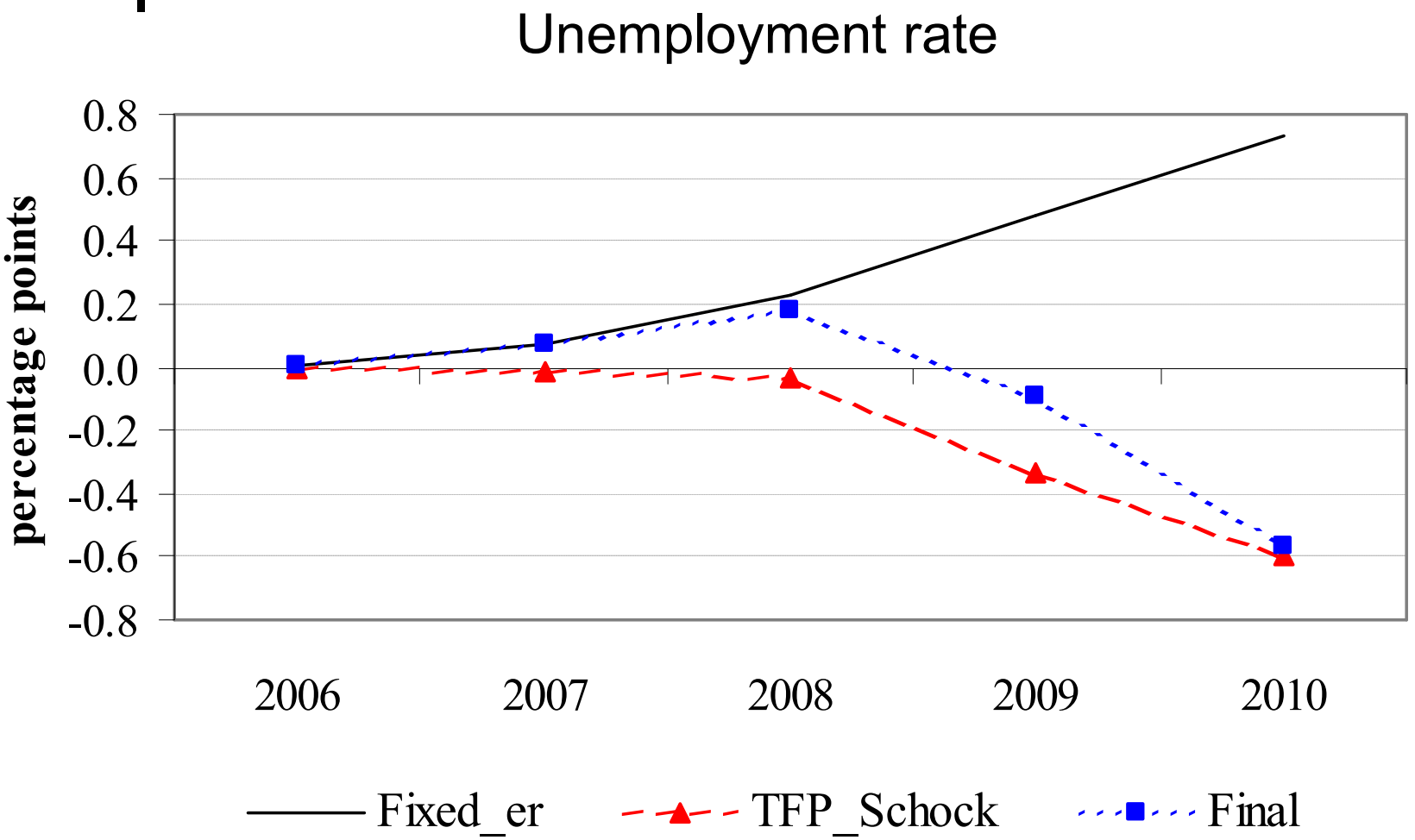
Deviations from baseline in percentage points

Simulation results



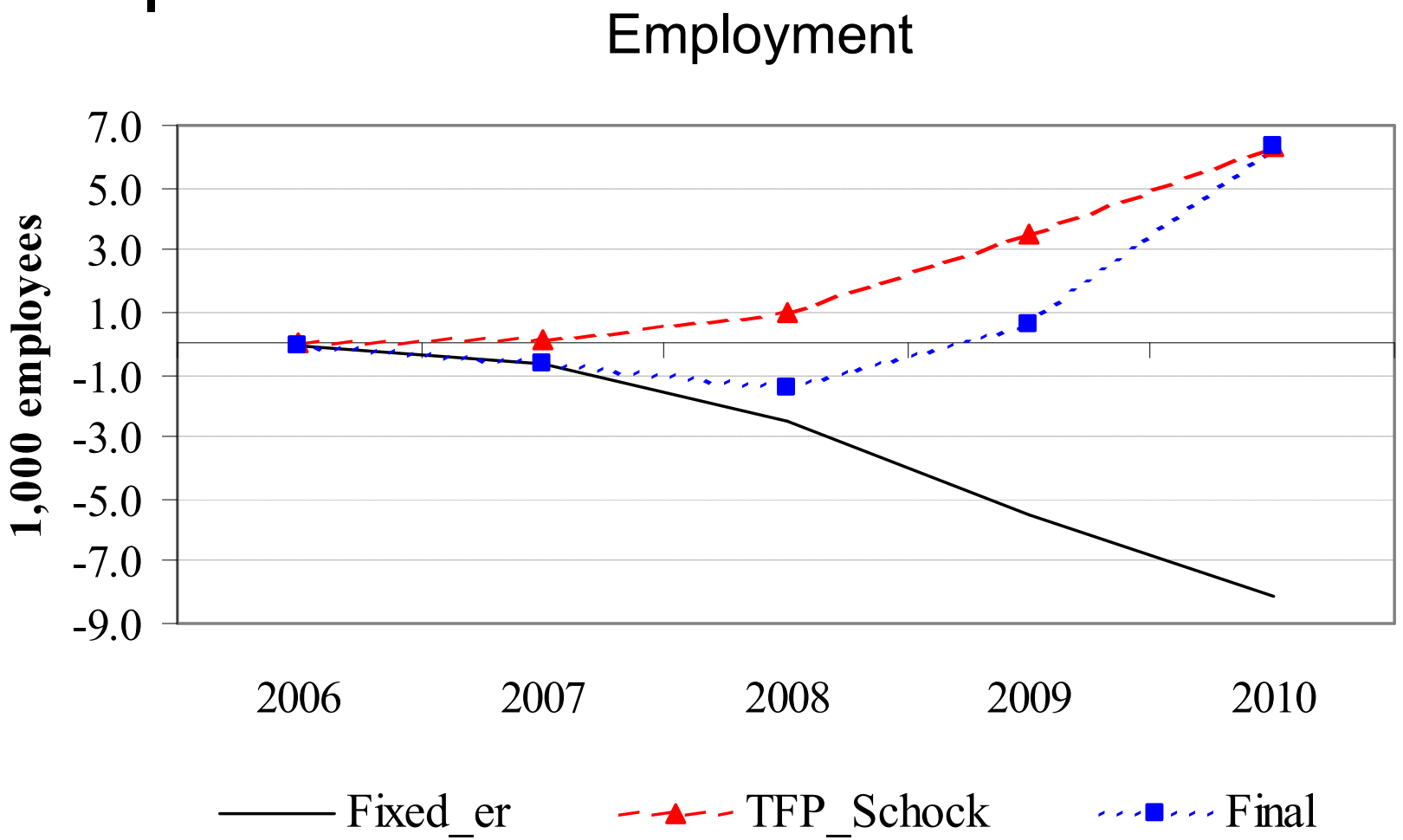
Deviations from baseline in percentage points

Simulation results



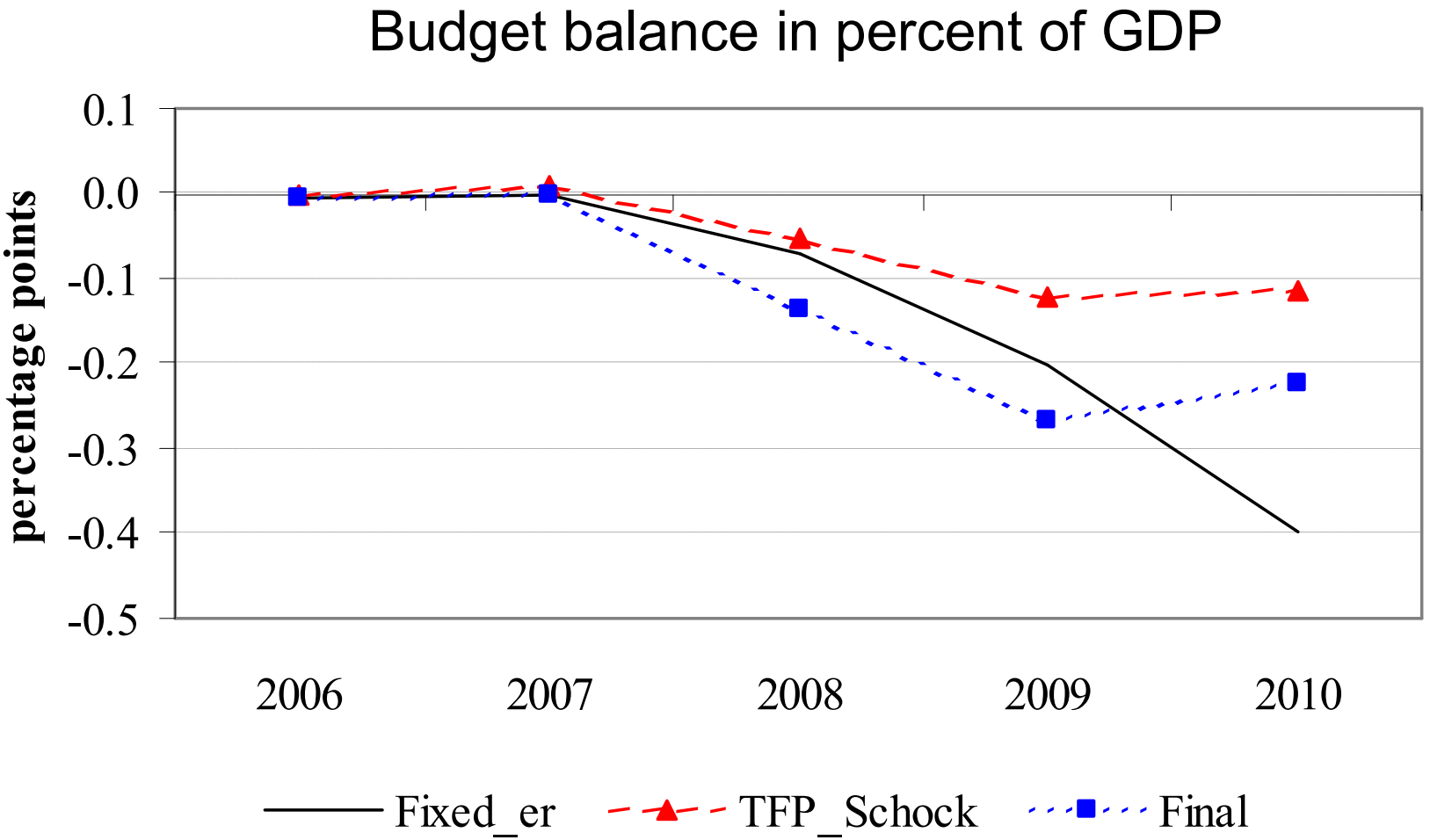
Deviations from baseline in percentage points

Simulation results



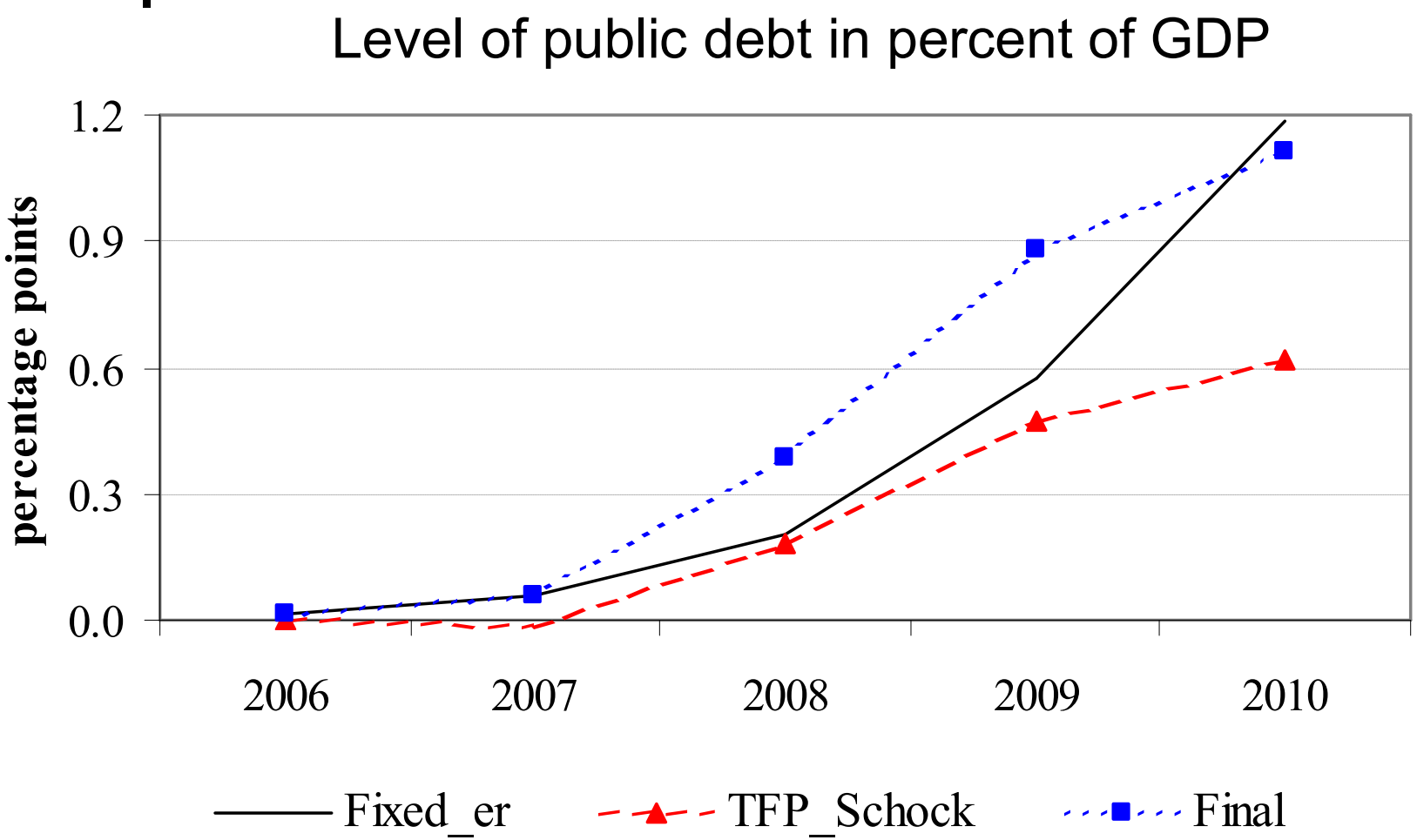
Deviations from baseline in 1,000 persons

Simulation results



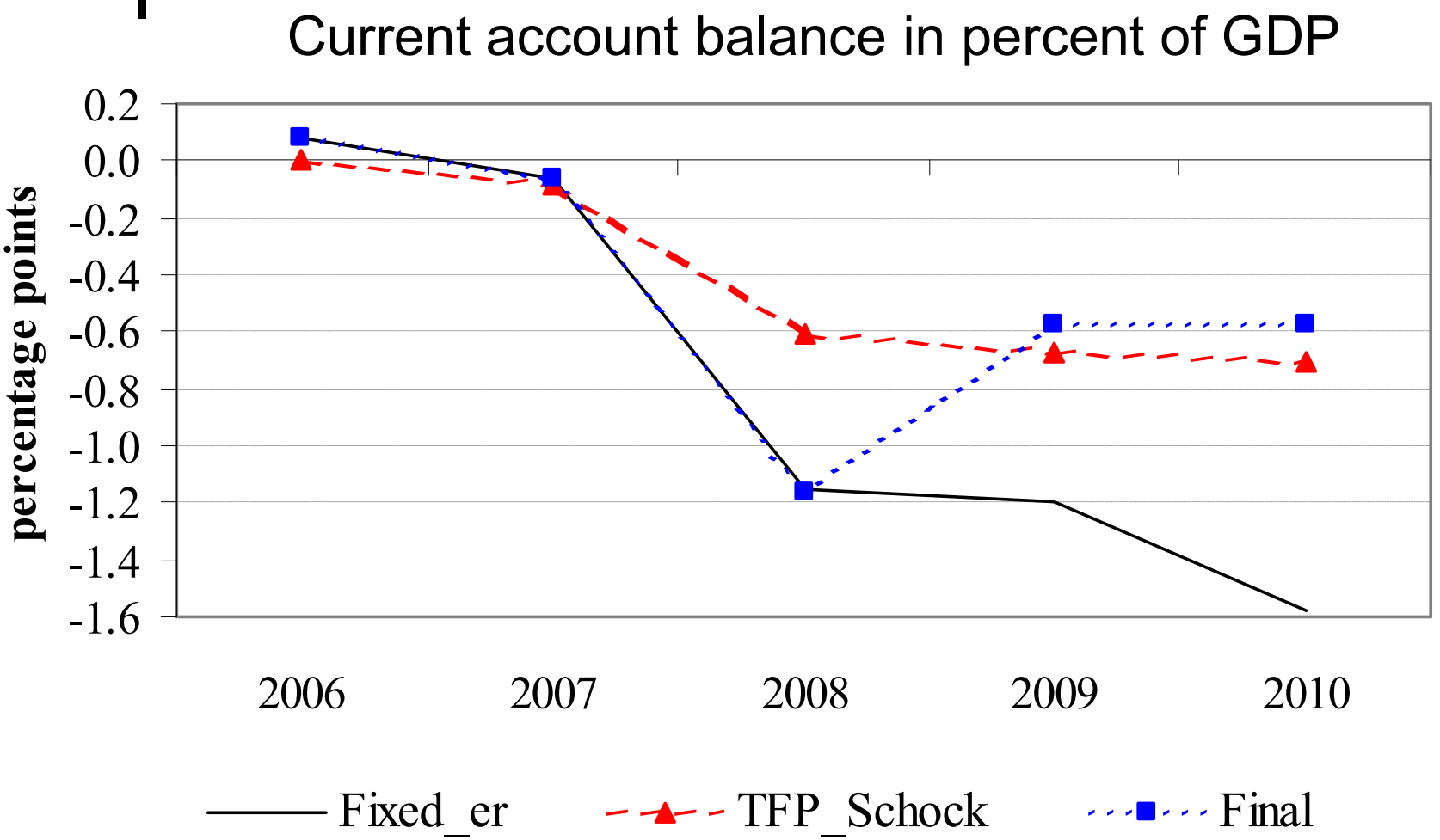
Deviations from baseline in percentage points

Simulation results



Deviations from baseline in percentage points

Simulation results



Deviations from baseline in percentage points

Summary: Simulation results

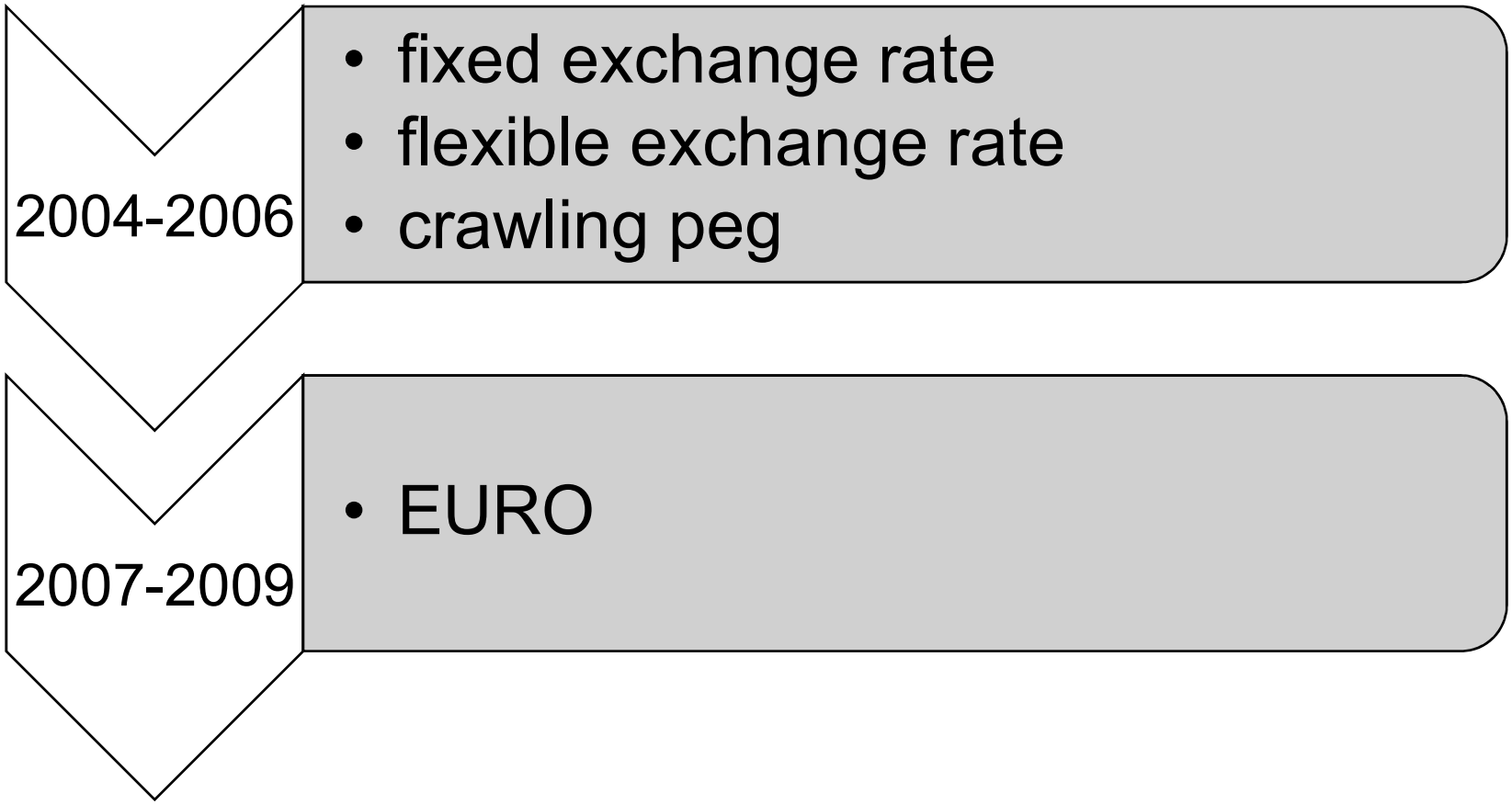
Macroeconomic effects of euro area integration positive, albeit relatively small:

- GDP *growth* temporarily higher
- GDP *level* permanently higher
- Employment permanently higher
- Inflation temporarily lower
- Price *level* permanently lower
- Current account deteriorates
  - stronger currency (depreciation in simulations without euro area accession)
  - higher GDP stimulates imports
- Isolated effects of common monetary policy are *negative*, due to loss of one policy instrument

Optimization Experiments

- Baseline simulations (2004-2009) for each exchange rate regime
- Exchange rate regimes for 2004-2006
  - Fixed
  - Flexible
  - Crawling peg
    - Decreasing rate of depreciation (2004: 1.5 percent; -0.5 percentage points / year)
- 2007-2009: Euro

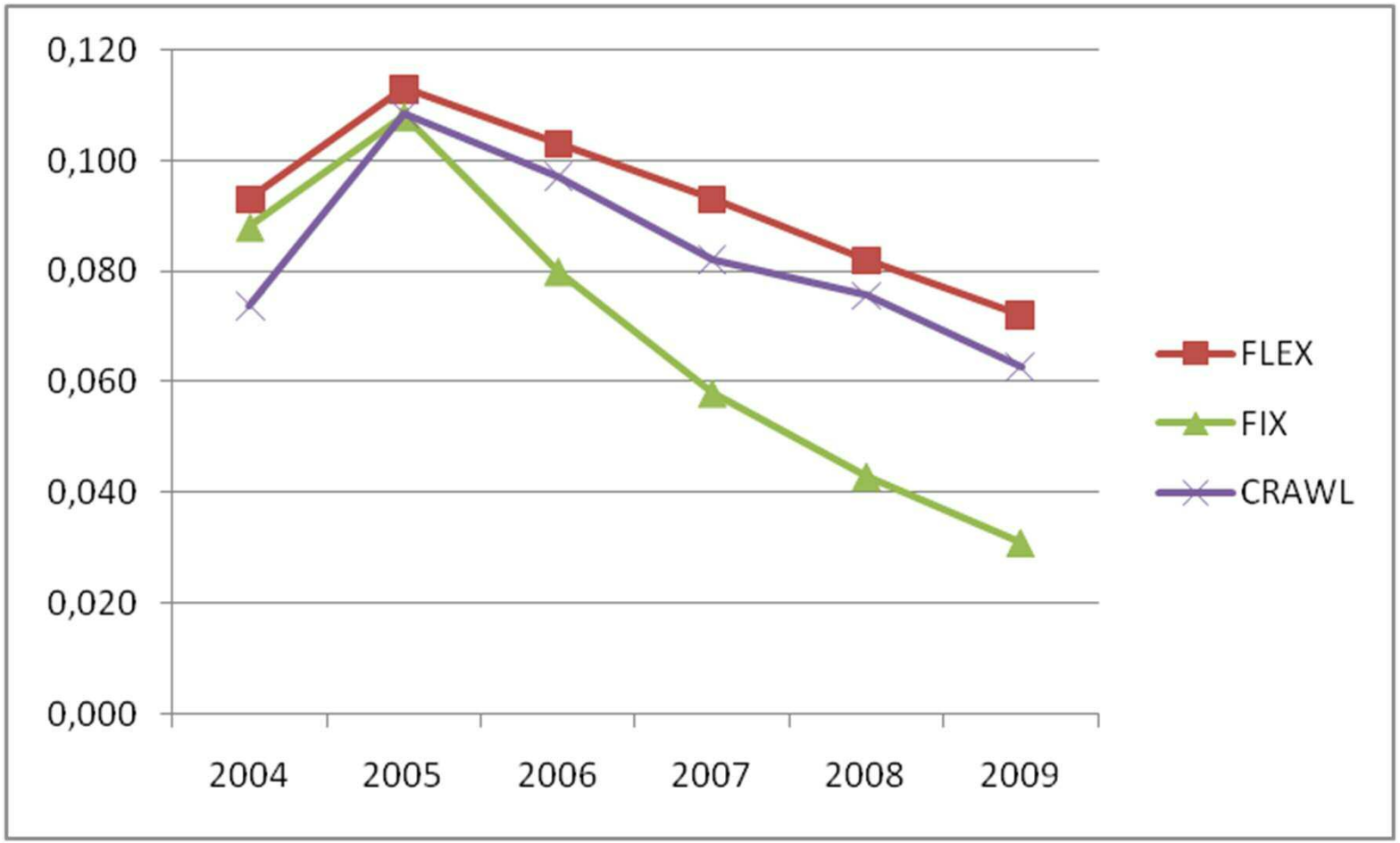
Exchange Rate Regime Overview



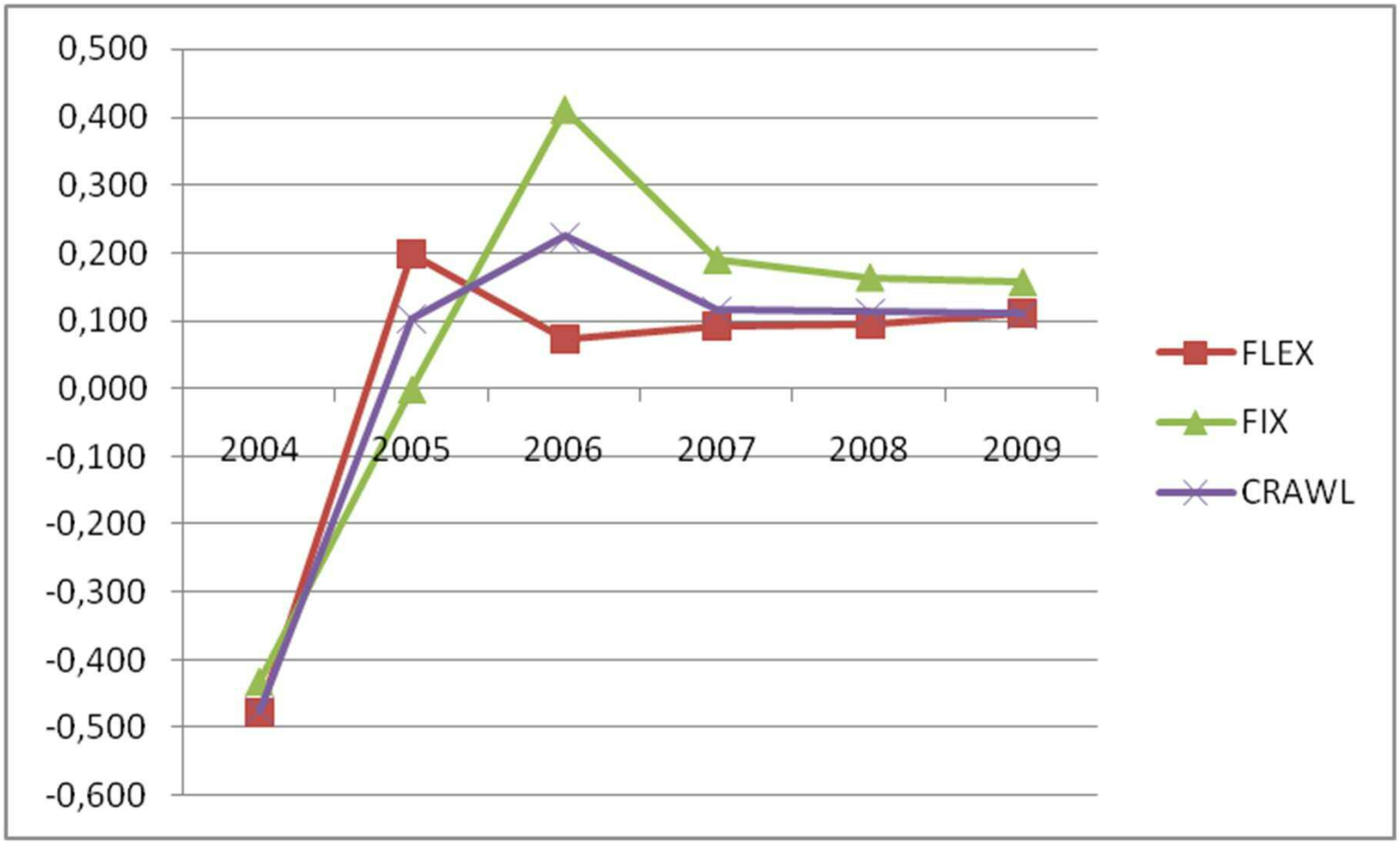
Optimization outline

- Algorithm: OPTCON 4 alpha (C#)
- Linear quadratic welfare loss function
  - Main targets
    - GDP, employment, inflation, fiscal deficit, current account
  - Minor targets
    - Consumption, investment, public consumption, exports, imports
  - Instruments
    - Public Consumption, transfers, labor tax “wedge”, (M2)
  - Discount rate: 1 (equal weights)
- Values are deviations from the corresponding simulation time paths

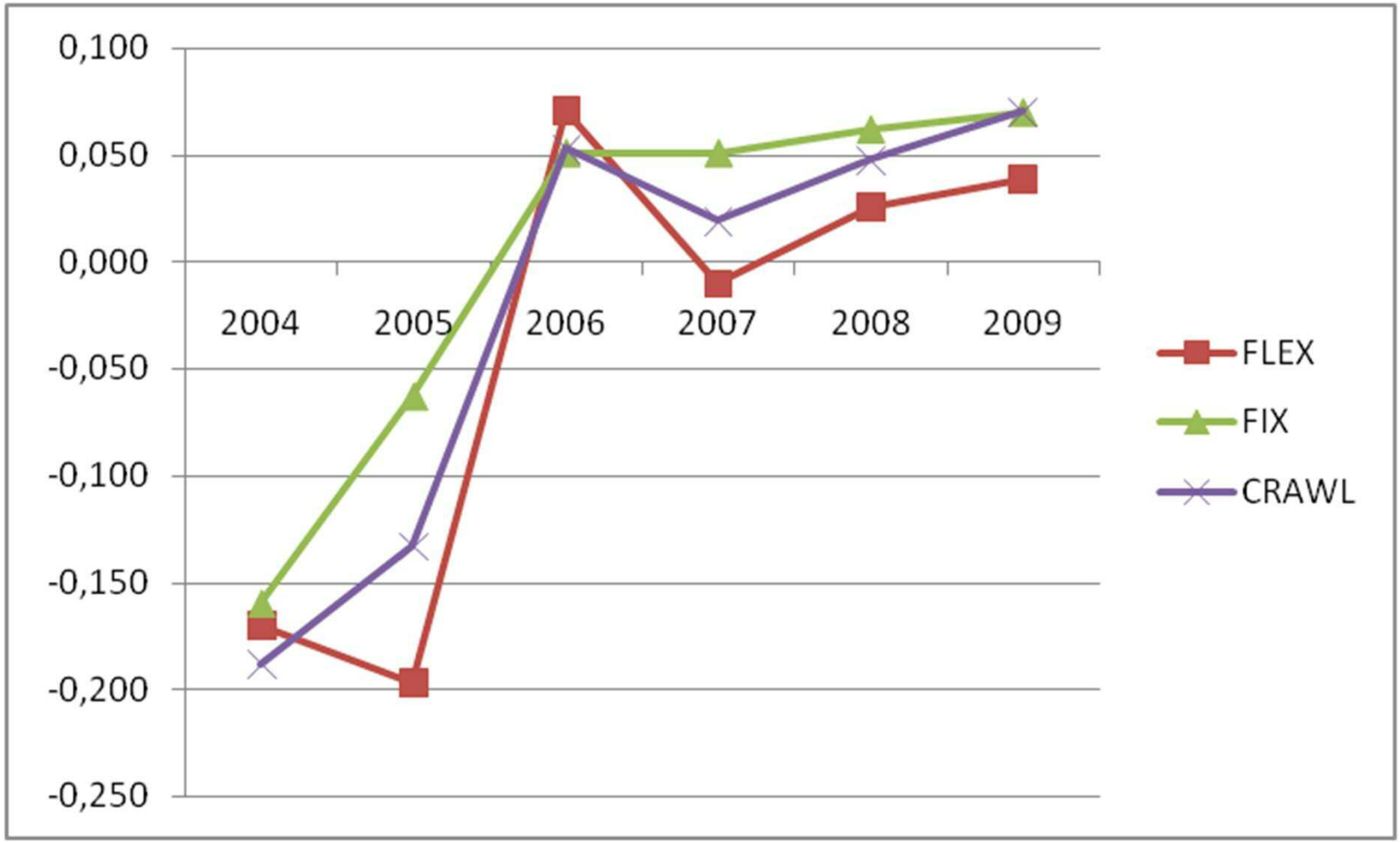
Unemployment Rate



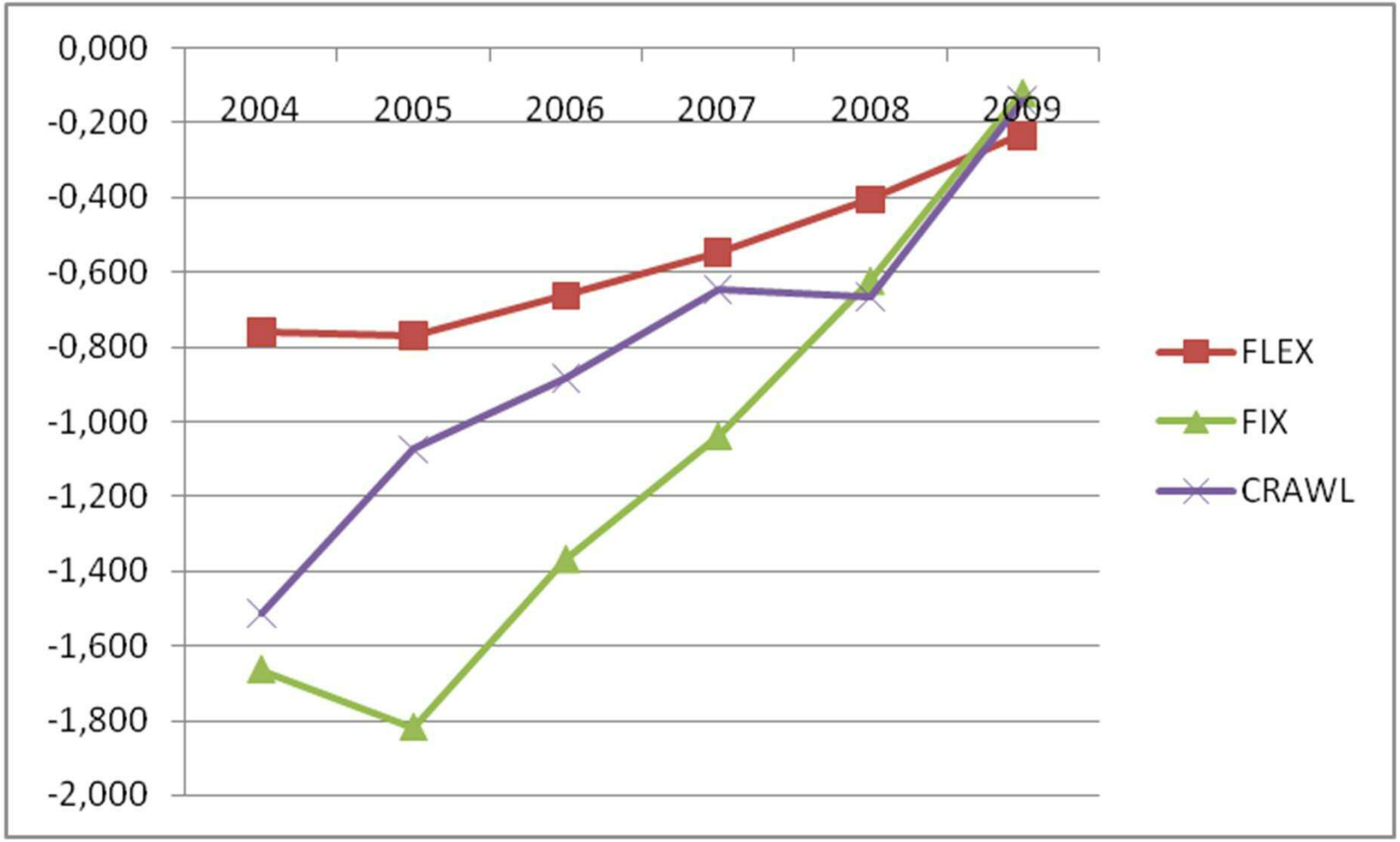
GDP Growth Rate



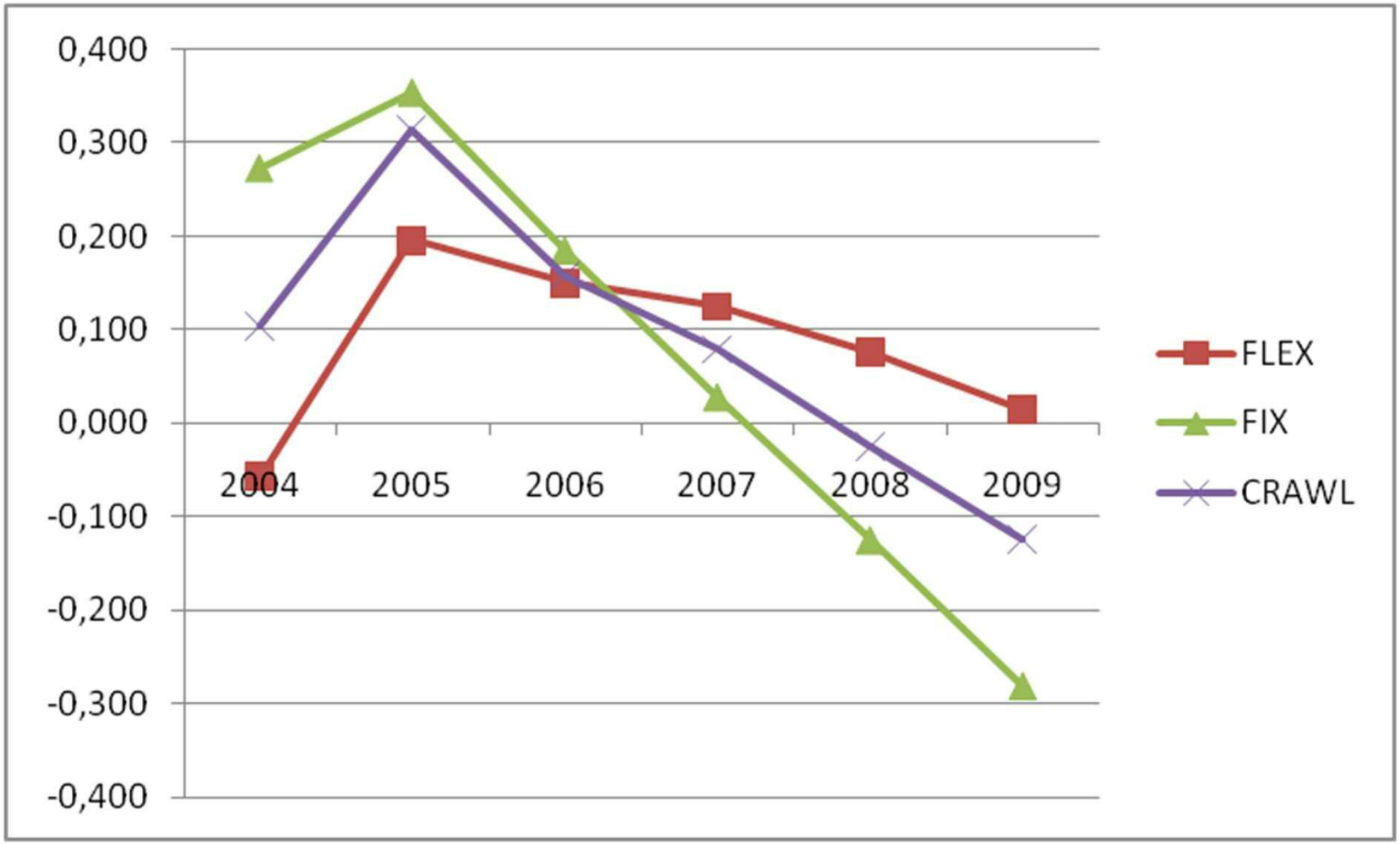
Inflation Rate



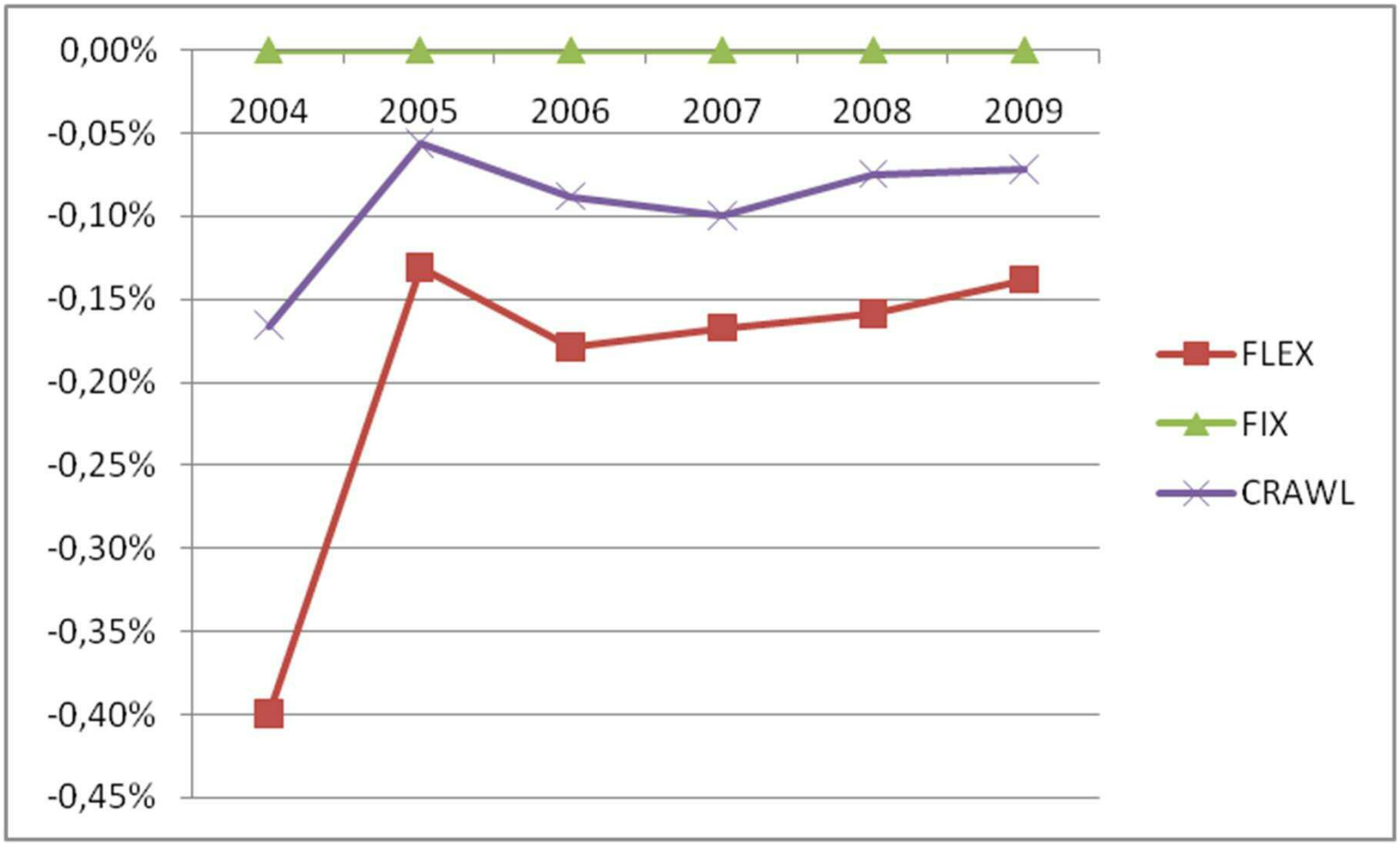
Deficit / GDP


0,000
-0,200
-0,400
-0,600
-0,800
-1,000
-1,200
-1,400
-1,600
-1,800
-2,000
2004
2005
2006
2007
2008
2009
FLEX
FIX
CRAWL

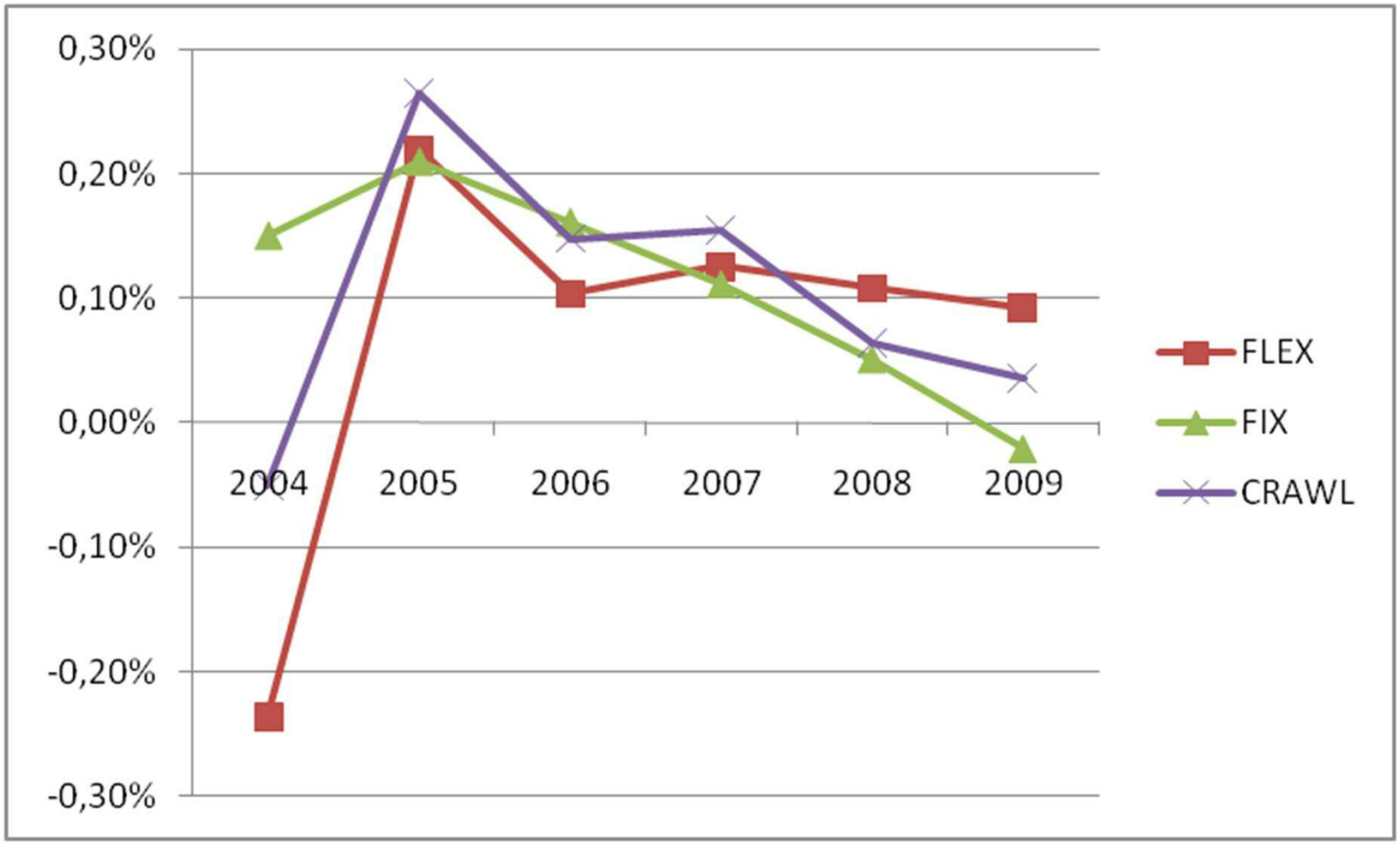
Current Account / GDP



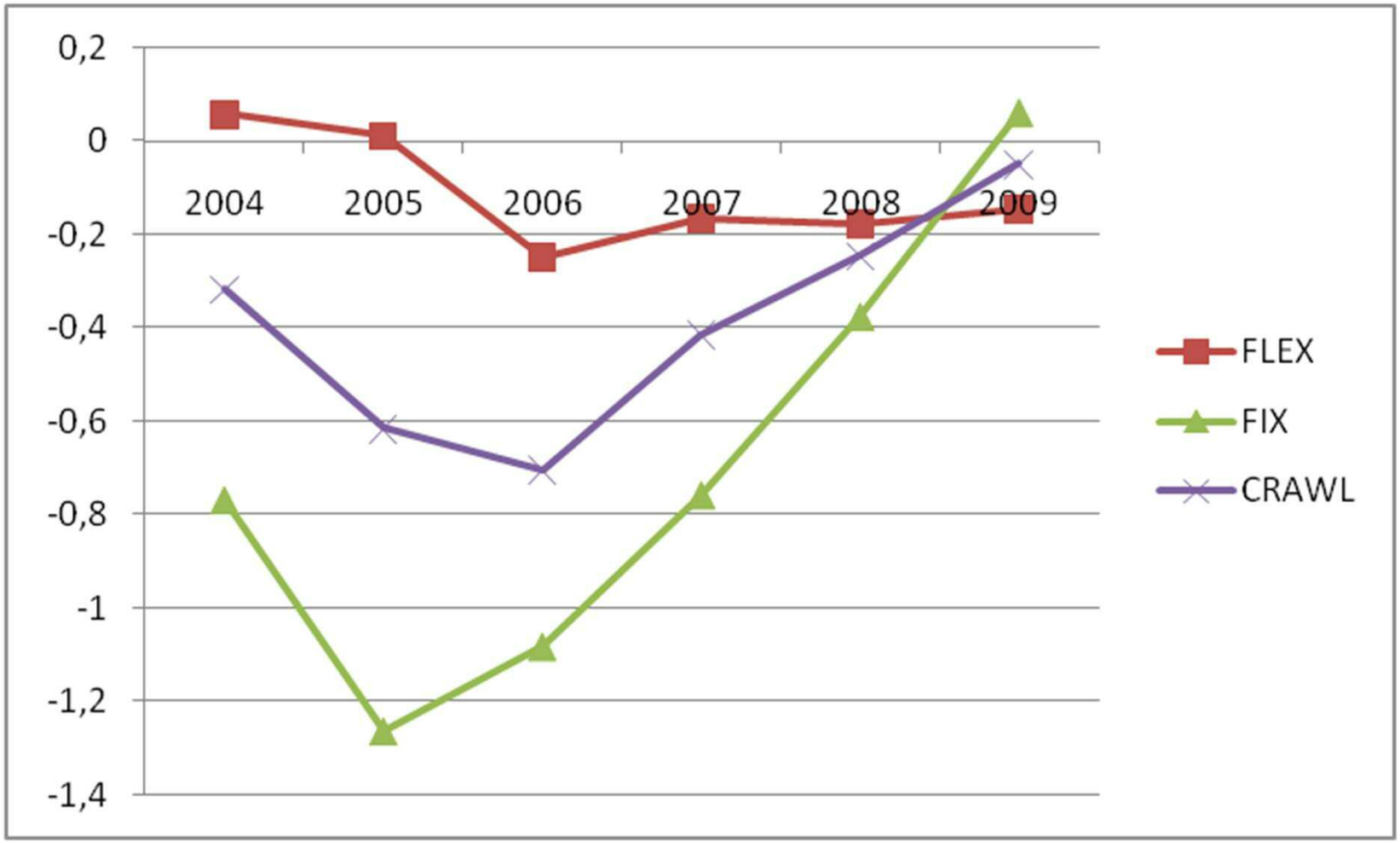
Nominal Exchange Rate



Real Exchange Rate



Real Long Term Interest Rate



Sensitivity Analyses

- Variations
  - Objective Function
    - Target variables
      - Labor tax
    - Weights
    - Discount factor
    - Optimization horizon
    - Target values
  - Optimization Horizon
  - Vector of control variables

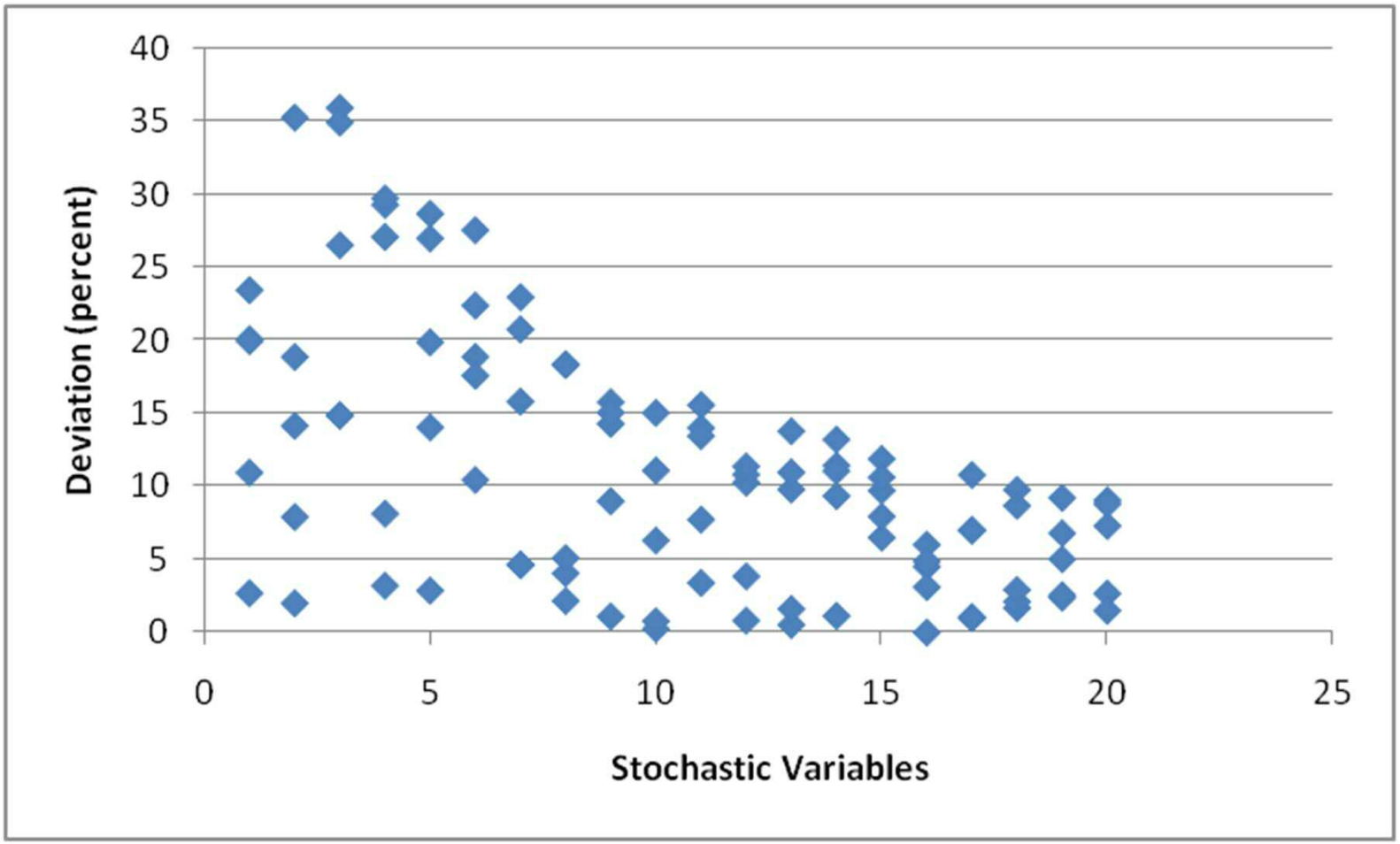
Sensitivity results:

- Higher weight of main objectives
  - More active policy (without loss of stability)
- Shorter time horizon
  - Less expansionary policy at the beginning, more expansionary at the end
- Labor taxes
  - Reduction would improve employment significantly

Stochastic Optimization

- Sensitivity analyses
  - Parameter uncertainty introduced
- Introduction of a stochastic term
  - Symmetrical increases
    - Maximum deviation of variables: 12.7 percent
  - Increases in single stochastic terms
    - Maximum deviation of variables: 37.4 percent
- Conclusion: results may be significantly altered by introducing (asymmetric) uncertainty

Asymmetric Stochastic Sensitivity



Final conclusion (for politicians)

Slovenia as a small open economy with high share of international trade with the other euro area countries and only little idiosyncratic, i.e. country-specific shocks benefits from Euro Area accession