Gli effetti di regimi salariali alternativi in una unione monetaria: un modello ad agenti.

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Introduzione I

Abbiamo sviluppato un modello che:

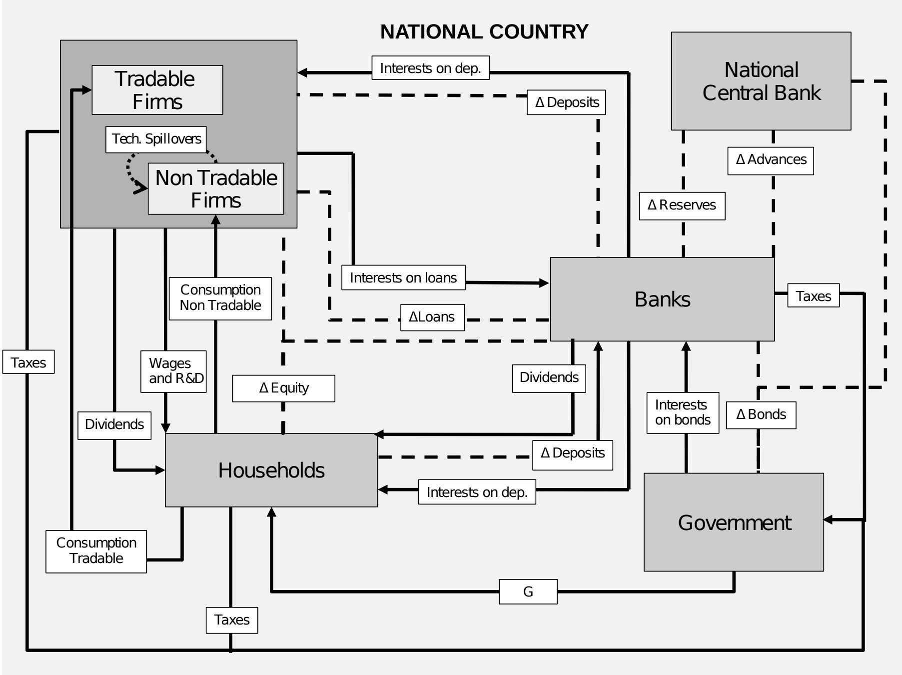
- combina i **Modelli ad Agenti** [e.g. Dosi et al., 2010, e lavori successivi] e gli approcci macro **Stock Flow Consistent** [Godley and Lavoie, 2007] [**AB-SFC models:** Deissenberg et al., 2008, Raberto et al., 2008, Assenza et al., 2015, Caiani et al., 2018b, e molti altri]
- **considera diversi paesi** [Wolf et al., 2013, Caiani et al., 2018a, Caiani and Caverzasi, 2017, as]...
- che interagiscono in una **unione monetaria** comparabile con l'EMU.

Introduzione II

Motivazione: verificare la "policy consensus view" sulla crisi dell'Euro che nei confronti dei paesi del Sud dell'Europa insiste su...

- leggerezza fiscale $\rightarrow$ consolidamento fiscale/programmi di austerità;
- mancanza di competitività (salari vs produttività) $\rightarrow$ riforme strutturali del mercato del lavoro.

- Caiani et al. [2018a] analizza l'impatto di regimi alternativi di **politica fiscale**.
- Qui analizziamo l'impatto di **cambiamenti del potere contrattuale dei lavoratori** all'interno dei singoli paesi solamente o cambiamenti coordinati a livello dell'Unione.


NATIONAL COUNTRY
Tradable Firms
Tech. Spillovers
Non Tradable Firms
National Central Bank
Interests on dep.
Δ Deposits
Δ Advances
Δ Reserves
Interests on loans
Banks
Taxes
Consumption Non Tradable
ΔLoans
Taxes
Wages and R&D
Δ Equity
Dividends
Dividends
Interests on bonds
Δ Bonds
Δ Deposits
Households
Interests on dep.
Government
Consumption Tradable
G
Taxes

Struttura dell'interazione internazionale:

- Il commercio internazionale origina **flussi internazionali di beni, depositi, e riserve**.
- Le imprese possono richiedere **crediti sia da banche domestiche e internazionali**.
- Le banche acquistano **sia bonds nazionali sia esteri**.
- **Spillovers** tecnologici nel settore tradable.

Ma...

- **No** Mobilità internazionale del lavoro.
- **No** FDIs (gli investimenti delle famiglie sono solo in azioni di imprese e banche domestiche).

Il Mercato del Lavoro - Offerta

I lavoratori offrono una quantità fissa di lavoro $l^S = 1$.

I lavoratori hanno un **salario di riserva** ($w_{h,t}$), **rivisto adattivamente** basato sulla situazione occupazione precedente dei singoli agenti e sul tasso di disoccupazione nazionale (u_t):

$$w_{h,t} = \begin{cases} w_{h,t-1}(1 + U[0,\delta]), & \text{if } l^S - l_{h,t-1} = 0 \text{ with } Pr(u_t) = \upsilon_H e^{-\upsilon u_{t-1}} \\ w_{h,t-1}(1 - U[0,\delta]), & \text{if } l^S - l_{h,t-1} > 0 \text{ with } Pr(u_t) = 1 - \upsilon_H e^{-\upsilon u_{t-1}} \end{cases} \quad (1)$$

Il Mercato del Lavoro - Domanda

la quantità prodotta dalle imprese si basa sulle aspettative di vendita (q^e_{it}) e sulle scorte (inv_{it}):

$$q^D_{it} = q^e_{it}(1+\theta) - inv_{it} \tag{2}$$

La **domanda di lavoro** dipende dal livello dell'output (q^D_{it}) e dalla produttività del lavoro (ϕ_{it}):

$$l^D_{it} = q^D_{it}/\phi_{it} \tag{3}$$

Il **salario offerto dalle imprese** cambia in relazione alla differenza tra lavoro domandato e lavoro attualmente impiegato:

$$w_{i,t} = \begin{cases} w_{i,t-1}(1+U[0,\delta]), & \text{if } l^D_{i,t-1} - l_{i,t-1} > 0 \text{ with } Pr(u_t) = \upsilon_F e^{-\upsilon u_{t-1}} \\ w_{i,t-1}(1-U[0,\delta]), & \text{if } l^D_{i,t-1} - l_{i,t-1} = 0 \text{ with } Pr(u_t) = 1 - \upsilon_F e^{-\upsilon u_{t-1}} \end{cases} \tag{4}$$

Cambiamento tecnologico

Seguiamo la tradizione evoluzionistica[Nelson and Winter, 1977, 1982, Winter, 1984, Dosi et al., 2010, Caiani et al., 2018b].

Le imprese investono una frazione costante delle loro vendite **R&D**.

$$R\&D^{D}_{i,t} = \gamma p_{i,t-1} q_{i,t-1} \tag{5}$$

Più grande è l'investimento, più alta è la probabilità di successo.

$$Pr_{success_{i,t}} = 1 - e^{\frac{-\nu R\&D_{i,t}}{\Phi_{k,t} P_{k,t}}} \tag{6}$$

Regimi salariali

Meccanismo di revisione dei salari di lavoratori e imprese:

$$w_{h,t} = \begin{cases} w_{h,t-1}(1+U[0,\delta]), & \text{if } l^S - l_{h,t-1} = 0 \text{ with } Pr(u_t) = \upsilon_H e^{-\upsilon u_{t-1}} \\ w_{h,t-1}(1-U[0,\delta]), & \text{if } l^S - l_{h,t-1} > 0 \text{ with } Pr(u_t) = 1 - \upsilon_H e^{-\upsilon u_{t-1}} \end{cases}$$

$$w_{i,t} = \begin{cases} w_{i,t-1}(1+U[0,\delta]), & \text{if } l^D_{i,t-1} - l_{i,t-1} > 0 \text{ with } Pr(u_t) = \upsilon_F e^{-\upsilon u_{t-1}} \\ w_{i,t-1}(1-U[0,\delta]), & \text{if } l^D_{i,t-1} - l_{i,t-1} = 0 \text{ with } Pr(u_t) = 1 - \upsilon_F e^{-\upsilon u_{t-1}} \end{cases}$$

Accrescendo (riducendo) υ le revisioni verso l'alto dei salari sono meno (more) probabili mentre quelle verso il basso diventano più (meno) probabili.

$$\Downarrow$$

Moderazione dei salari (Inflatione)...

- In 1 o più paesi
- Con 2, 5, 10, 15 paesi.
- Con diverse sensitività dei consumatori a differenze di prezzo

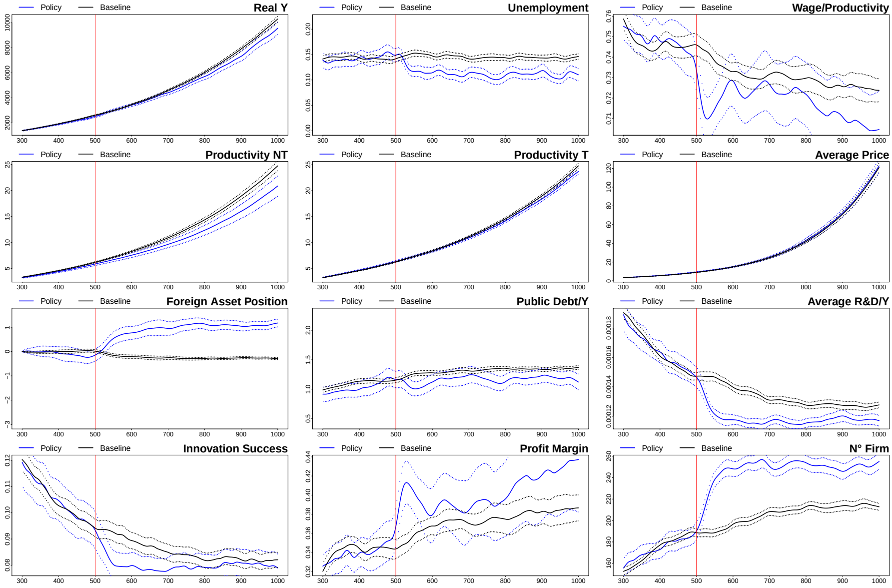


Figure: Wage moderation in one randomly-chosen country.

Moderazione salariale in un solo paese

Breve-medio periodo

- Inizialmente migliora la competitività internazionale: il PIL cresce anche con una domanda interna minore;
- Migliora il profitto delle imprese, il debito pubblico e si riduce il debito estero;
- La minore disoccupazione in parte contrasta la riduzione dei salari.

Ma nel lungo periodo

- Indebolisce il processo di selezione delle imprese, anche le meno competitive riscono a sopravvivere;
- Più imprese, più piccole e meno produttive More, smaller, less productive firms;
- L'investimento medio in R&D diminuisce: R&D è dispersa in una miriade di piccole imprese;
- Innovazione e crescita della produttività del lavoro rallentano;

Vantaggi esterni sono erosi nel lungo periodo e una indebolita domanda interna rallenta la crescita economica.

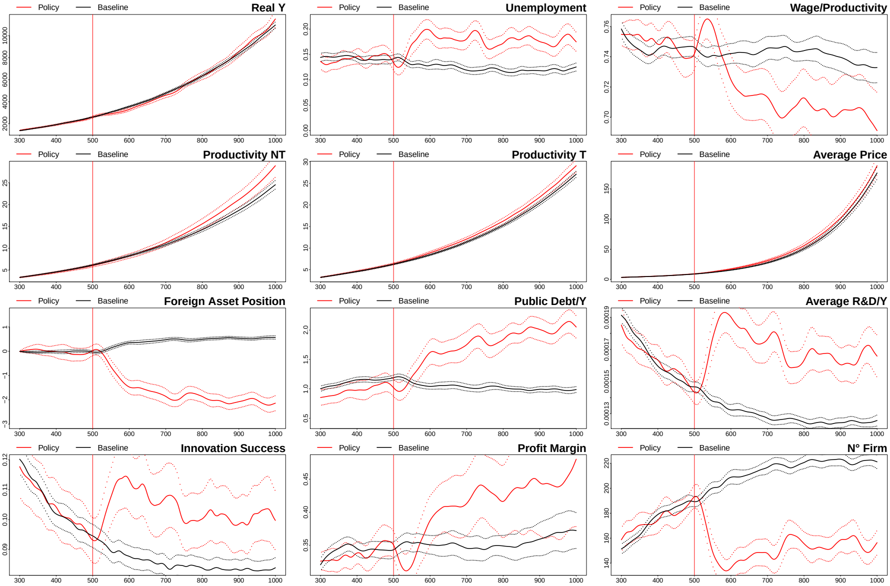


Figure: Wage inflation in one randomly-chosen country.

Accelerazione dei salari in un solo paese

breve-medio periodo:

- Inizialmente si riduce la competitività internazionale. Il PIL rallenta anche se la domanda domestica è più alta;
- Diminuisce il profitto delle imprese, cresce il debito estero e peggiora il debito estero.

ma nel lungo periodo:

- La crescita della disoccupazione contrasta l'effetto inflazionistico sui salari;
- Si rafforza il processo selettivo delle imprese, solo le più produttive riescono a sopravvivere;
- Meno imprese, più grandi e più produttive;
- L'investimento medio in R&D è maggiore: la R&D è concentrata in meno imprese che sono più grandi, quindi non si disperde tra molte piccole imprese;
- L'innovazione e la produttività del lavoro accellerano accrescendo al competitività internazionale.

Inflation vs Moderazione salariale in un paese: Effetti globali sull'unione monetaria

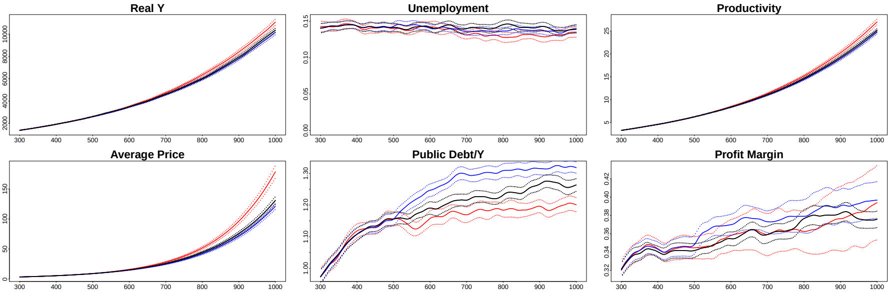


Figure: Wage acceleration vs wage moderation in one randomly-chosen country: global effects on the Union. Black: baseline, red: wage acceleration, blue: wage moderation.

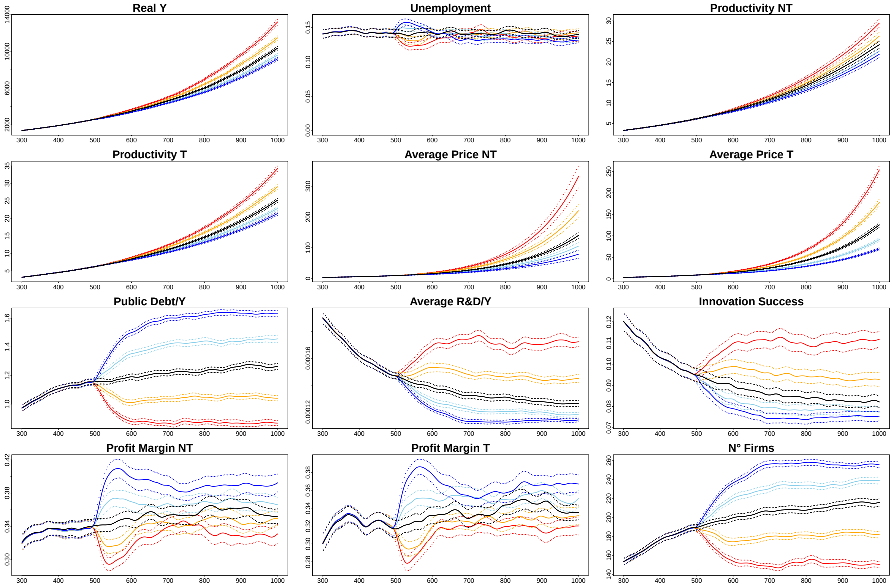


Figure: Alternative Wage Growth Patterns in all countries. Black line: baseline scenario ($\upsilon = 1.625$). Red line: wage acceleration with $\upsilon = 0.512$. Orange line: wage acceleration with $\upsilon = 1.054$. Light blue line: wage moderation with $\upsilon = 2.231$. Blue

Accelerazione vs Moderazione salariale in tutti i paesi

Se **tutti i paesi** seguono la stessa dinamica di crescita dei salari **i vantaggi competitivi dovuti a diversi regimi salariali si annullano**

Gli incrementi della domanda nominale domestica dovuta a salari più alti crea **feedback positivi tra i paesi** e viceversa

Gli **effetti del processo di selezione schumpeteriano tra le imprese rimangono**: bassi salari permettono alle imprese meno produttive di sopravvivere, riducendo la crescita delle più produttive e riducendo la R&D media delle imprese. Invece salari più alti conducono ad un mercato più concentrato con imprese più produttive e con un livello più alto di spesa in ricerca.

Conclusioni

Importanza dell'**interrelazione tra effetti sulla domanda e offerta**.

la moderazione salariale in un solo paese è efficace nel breve periodo e controproduttiva nel lungo. Mentre l'accellerazione salariale ha costi nel breve periodo e guadagni nel lungo.
In una economia chiusa (i.e. l'unione monetaria nel suo complesso) **la crescita sembra essere wage-led** (see Caiani et al. [2018b] and Caiani et al. [2018c]).

Sensitivity Analysis usando Salle and Yildizoglu [2014]. Regimi salariali alternativi...

- un numero diverso di paesi → l'impatto dei regimi salariali è simile in 2, 5, 10, 15 paesi.
- Differenti elasticità della domanda dei consumatori ai prezzi → i risultati sono rinforzati con alte elasticità, più deboli con quelle basse.

Limiti, miglioramenti, lavori futuri

Il **lato finanziario** è molto semplificato, e non considera il ruolo degli **investimenti diretti esteri**.

$$\Downarrow$$

I flussi finanziari internazionali sono determinati essenzialmente dal commercio estero: nella realtà **transazioni internazionali autonome** possono essere fondamentali.
Introdurre **paesi inizialmente differenziati** in rispetto a dimensioni, produttività, debito ecc..

Thank you

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Calibration of Initial Stocks&Flows Back

A simple and intuitive method to calibrate initial stocks and flows in an SFC manner, respecting **Copeland's quadruple entry principle** [Copeland, 1949, Godley and Lavoie, 2007]:

- **we start from a situation where there are no stocks in the economy**, and we let them to be progressively created and accumulated during the simulation thanks to an initial injection of money through public spending.
- Similarly, **initially no banks and firms**: these are endogenously created during the initialization phase.

The Initialization Phase I

- **Public spending** as the government makes an initial transfer to resident households.
- The **national Central Banks buy government bonds**, providing in this way the **legal currency**.
- This money is **saved and invested in the creation of new firms**.
- The **government** starts to **collect taxes** on income and profits.
- As firms' number increases also **banks are created**.
- Banks also start to grant **credit to firms**.
- Banks' **start to buy bonds**.
- **International flows of goods, deposits and reserves** between countries arise.
- **Supranational credit-debt relationships**, generating international flows of interests also arise.
- **The model exits its transition phase** and starts to display stable properties.

Table: Parameters

K: Number of countries	5	μ_2: Minimal reserve requirement parameter	0.1
H: Number of Households	500	ι_l: Loan probability parameter	0.5
l^S: Workers' labor supply	1.0	χ: Loan interest parameter	0.003
ψ: Matching parameter	10	ι_b: Bond probability parameter	0.1
υ: Wage revision probability parameter	1.625	r_{re}: Interest paid on banks' reserves	0.0
υ_H: Wage revision probability households	0.7	r_{b0}: Initial interest on bonds	0.001
υ_F: Wage revision probability firms	1.0	w_0: Initial wage	1.0
ϕ_0: Initial productivity	1.0	$\bar{r}$: Taylor rule long run interest rate	0.0075
τ_0: Initial tax rate	0.4	ξ: Taylor rule adjustment speed parameter	0.8
c_y: Propensity to consume out of income	0.9	$\xi^{\Delta P}$: Taylor rule sensitivity to inflation	2
c_D: Propensity to consume out of wealth	0.1	$\overline{\Delta P}$: Inflation Target	0.005
δ: Adaptive Parameter	0.03	d^{max}: Maximum deficit-GDP ratio	0.03
c_T: Share of tradable	0.4	tau_{min}: Minimum tax rate	0.35
β: Hotelling circle parameter	2.0	tau_{max}: Maximum tax rate	0.45
λ: Liquidity preference parameter	0.2	g_{min}: Minimum G/GDP	0.4
θ: Share of sales as inventories	0.2	g_{max}: Maximum G/GDP	0.6
γ: R&D expenditure parameter	0.03	η: Banks-firms minimum proportion	0.1
ν: R&D success probability parameter	0.8	ϖ: Minimum investment threshold parameter	0.1
ρ: Share of profits distributed	0.95	A^0: First firms' initial net worth	10.0
ζ: Deposit interest-discount rate ratio	0.1	σ: Banks' minimum dimension relative to firms	4
μ_1: Total credit supply parameter	20		

Table: Baseline summary

Variable	Simulations 2 Countries	5 Countries	10 Countries	15 Countries	Euro Area 1999-2007
Real GDP Growth	1.2 (0.054)	1.1 (0.054)	1.1 (0.047)	1.1 (0.050)	2.3
Real Labor Productivity Growth	1.2 (0.054)	1.1 (0.055)	1.1 (0.047)	1.09 (0.050)	Total Economy: 0.9 Manufacturing only: 3.3
Inflation	2.3 (0.090)	2.2 (0.074)	2.1 (0.110)	2.1 (0.047)	2.2***
Unemployment	12.6 (1.13)	14.0 (0.818)	14.5 (0.596)	14.6 (0.484)	8.8
Public Debt/GDP	124.4 (18.215)	122.2 (29.627)	122.6 (33.600)	122.9 (33.151)	68.3
Public Deficit/GDP	1.0 (0.291)	1.1 (0.162)	1.0 (0.291)	1.0 (0.279)	2.0
Private Debt/GDP	138.6 (11.571)	127.7 (9.301)	123.79 (6.672)	123.43 (6.556)	122.1**
Exports/GDP	18.5 (0.581)	29.5 (0.286)	33.1 (0.199)	34.28 (0.349)	35.4
Imports/GDP	18.5 (0.612)	39.5 (0.581)	33.1 (0.212)	34.33 (0.349)	33.8
Public Expenditure/GDP	45.4 (1.010)	46.5 (0.788)	46.8 (0.583)	46.9 (0.539)	46.6
R&D Investment/GDP	2.8 (0.066)	2.7 (0.051)	2.7 (0.027)	2.7 (0.039)	1.8*
Household investment to GDP	8.7	8.7	8.6	8.6	6.9

Timing Back

- Previous period dividends paid to equity holders.
- Firms decide: production levels, labor demand, prices, wage offered, and desired R&D.
- Firms ask loans to banks. Banks ask cash advances to the Central Bank if needed.
- Firms interact with workers on the labor market.
- Workers paid and employed in production and R&D.
- Governments make public expenditure, compute revenues from taxes (on past profits and current income), decide public expenditure and the tax rate for the next period, repay old bonds+interests, and issue new bonds.
- Bonds are purchased by commercial banks (and national Central Banks for the residual part).
- Households consume interacting with tradable and nontradable firms.
- Firms and banks compute profits.
- Defaulted firms and banks exit the market. Households equity investment takes place and new firms and banks are created.

Some relevant Stylized Facts Back I

- The **volatility** of consumption is slightly below the volatility of real GDP, whereas exports, imports, and unemployment are significantly more volatile than real GDP;
- **Consumption, exports and imports are positively correlated** with GDP [Uribe and Schmitt-Grohé, 2017], with the only exception of imports in the two-country case;
- **Real public expenditure is pro-cyclical in levels** whereas **public expenditure over GDP is strongly counter-cyclical** (i.e. government expenditure increases with GDP, but less than proportionally);
- **Unemployment** is strongly **countercyclical**;
- **Firms and banks significantly differ** with respect to their size, and their **size distributions** is right skewed and display excess kurtosis and **fat tails** under all scenarios.
- **Inflation in nontradables is higher than in tradables**, whereas **labor productivity growth in nontradables is lower than in tradables** [De Gregorio et al., 1993, Bernard et al., 2003, 2007].
- **Countries can significantly and persistently diverge** in terms of real GDP and productivity levels;

Model General Structure I

A Monetary Union composed of K **countries**.

In each country:

- H households
- An **endogenously varying number of firms** (I_t) **and banks** (Z_t), depending on households' equity investment .
- Firms subdivided into **'tradable'** (produce for common market) and **'nontradable'** (produce for domestic market).
- A government (+) and a national CB (+).

Consumption Market

Firms **revise the price** of their output according to their past sales performance.

Households' desired consumption is a function of disposable income y_{ht} and deposits D_{ht}.

$$C_{ht}^{D} = c_y y_{ht}^{D} + c_d D_{ht} \tag{7}$$

Total **demand distributed between tradables and nontradables** with fixed proportions c_T and $1 - c_T$.

Consumers observe ψ suppliers and rank them according to a function of the **price charged** $p_{i,t}$ and the **distance** $d_{h,i}$ between consumer's preferences and firms' varieties (**Hotelling's locational specification** [Salop, 1979]).

$$u_{h,i,t} = \frac{1}{d_{h,i}^{\beta}} \frac{P_t}{p_{i,t}} \text{ with } \beta \geq 0 \tag{8}$$

Equity investment +

Households allocate savings between **deposits** D_{ht} and **participations in the equity** of firms and banks A_{ht} comparing their **past rates of return**.

- Deposits are safe assets.
- Return on past equity investments weighted by the past extinction rate of firms and banks.

Households having a positive desired investment act together as **entrepreneurs to create a new firm or a new bank**.

- New entry if equity investment great enough.
- Exit(s) if a firm/bank is insolvent or its equity shrinks to almost 0.

Reserves and Bond Markets

Firms production and pricing

Firms produce based on sales expectations and past inventories:

$$q_{it}^{D} = q_{it}^{e}(1+\theta) - inv_{it} \tag{9}$$

Prices and sales expectations are revised adaptively by a percentage sampled from $U[0, \delta]$:

- If past sales $\geq$ expectations: increase both sales expectations and price.
- If past sales $<$ expectations and no supply constraint: decrease both expectations and price.
- If sales below expectations due to supply constraints: no revision.

Yet: $p_{it} \geq \frac{w_{it}}{\phi_{it}}$

Back

Income and Profits

Households' gross **income** is expressed by:

$$y_{ht} = \sum_{i}^{n} w_{hit} l_{hit} + r_{dt} D_{ht} + Div_{ht} + \sum_{i}^{n} IN_{ht} \frac{l_{hit}}{l_{it}} \tag{10}$$

Firms' profits are defined as:

$$\pi_{it} = p_{it} q_{it} + r_{dt} D_{it} + \Delta INV_{it} - w_{it} l_{it} - IN_{it} - r_{it} L_{it} \tag{11}$$

Banks' profits are equal to:

$$\pi_{zt} = \sum_{i}^{n} r_{it} L_{izt} + r_{bt} B_{zt} + r_{re} R_{zt} - BD_{izt} - r_{dt} D_{zt} - r_t L_{zCBt} \tag{12}$$

where (BD_{izt}) indicates the **"bad debt"**.
When profits are positive firms and banks **pay taxes** and **distribute** dividends to equity holders proportionally to the share of equity they own.

Back

Equity investment I

Households allocate savings between **deposits** D_{ht} and **participations in the equity** of firms and banks A_{ht} comparing their **past rates of return**.

- Deposits are safe assets.
- Return on past equity investments weighted by the past extinction rate of firms and banks.

$$
Ip_{h,t} = \begin{cases} \lambda e^{-\left(\frac{Div_{h,t-1}}{A_{h,t-1}}(1-Pr_t^{default})-r_{dt}\right)} & \text{if } \frac{Div_{h,t-1}}{A_{h,t-1}} \geq r_{dt} \text{ and } A_{h,t-1} \geq 0 \\ \lambda & \text{if } \frac{Div_{h,t-1}}{A_{h,t-1}} < r_{dt} \text{ or } A_{h,t-1} = 0 \end{cases} \tag{13}
$$

with $0 < \lambda < 1$.

Households having a positive desired investment act together as **entrepreneurs to create a new firm or a new bank**.

- New entry if equity investment great enough.

Equity investment II

- Exit(s) if a firm/bank is insolvent or its equity shrinks to almost 0. Deposits are guaranteed by the government.

New entrant's type:

- If the ratio between banks' and firms' number or the ratio between banks' and firms' total net worths $< \eta$: $\rightarrow$ **new entrant is bank**.
- Otherwise $\rightarrow$ **new entrant is a firm**.
  - The new firm will be a tradable with probability c_T or a non tradable with probability $1 - c_T$

New entrant's equity, labor productivity, initial price, wage offered, and sales expectations a random sample between the lowest and highest values of incumbent firms.

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Credit Market

Credit Demand:
When internal funding is insufficient, firms can ask **loans to both domestic and foreign banks** [Meyers, 1984].
Financially constrained if:

- banks have already exhausted their desired supply of loans
- due to individual credit rationing

Credit Supply:
Banks receive **credit applications from domestic and foreign firms**.
The **maximum supply of credit** is a multiple of their equity.

- The probability of granting the loan and the interest charged depend on the applicant's leverage.

Reserves and bond market

Banks have minimal reserve requirements.
They **apply to the Central Bank lending facility** asking liquidity at the discount rate r_t when needed.

Reserves in excess with respect to the mandatory level **can be invested in the purchase of bonds** issued by any member country k.

- The **interest on bonds depends on the debt-to-GDP ratio** of the country (B_{kt}/Y_{kt}) and the discount rate (r_{kt}).
- Newly issued bonds **split into** 100 **equal tranches** and put on the market. Commercial banks buy randomly selected tranches with a probability decreasing in B_{kt}/Y_{kt}. National Central Banks purchase the possible residual part.

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Fiscal Policy I

The government determines the level of **public expenditure (G_{kt}) and the tax rate (τ_{kt})**.

- These are adaptively revised from period to period based on the **discrepancy between desired and past levels** of public expenditure on the one hand, and **expected and admissible (d^{max}) levels of public deficit** on the other hand.
- The desired level of public expenditure is a constant real value indexed for the country average level of prices and productivity so to keep it roughly stable compared to GDP.

Furhter details Back

Fiscal Policy II

Public expenditure and tax rates are then revised according to the following scheme:

$$\textit{if } d_{kt-1} \geq d^{max} \textit{ and } G^D_{kt} \leq G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1}(1 - U[0,\delta]) \\ \tau_{kt+1} = \tau_{kt}(1 + U[0,\delta]) \end{cases} \tag{14}$$

$$\textit{if } d_{kt-1} \geq d^{max} \textit{ and } G^D_{kt} > G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1} \\ \tau_{kt+1} = \tau_{kt}(1 + U[0,\delta]) \end{cases} \tag{15}$$

$$\textit{if } d_{kt-1} < d^{max} \textit{ and } G^D_{kt} \leq G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1}(1 - U[0,\delta]) \\ \tau_{kt+1} = \tau_{kt}(1 - U[0,\delta]) \end{cases} \tag{16}$$

$$\textit{if } d_{kt-1} < d^{max} \textit{ and } G^D_{kt} > G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1}(1 + U[0,\delta]) \\ \tau_{kt+1} = \tau_{kt} \end{cases} \tag{17}$$

The tax rate can vary within $\{\tau_{min}, \tau_{max}\}$, whereas G_{kt} is bound between $\{g_{min} Y_{kt}, g_{max} Y_{kt}\}$. Back

The System of Central Banks

The **Union Central Bank** is in charge of implementing the common monetary policy: she **sets the discount interest rate** following a Taylor rule based on the average level of inflation across member countries [Taylor, 1993, Smets and Wouters, 2007, Gerali et al., 2010].

National Central Banks hold reserves of commercial banks (R_{CBkt}), accommodate their requests for cash advances (L_{CBkt}), and possibly buy bonds issued by the country government (B_{CBkt}) not purchased by private banks.

Central Banks' profits automatically redistributed to the government.

$$\pi_{CBkt} = r_{bkt} B_{CBkt} + r_t L_{CBkt} - r_{re} R_{CBkt} \tag{18}$$

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Innovation Activities I

R&D expenditure is a share of the expected wage bill:

$$R\&D^D_{i,t} = \gamma p_{i,t} q^e_{i,t} \tag{19}$$

The **probability of success** of a firm operating in market X given by:

$$Pr^X_{success_{i,t}} = 1 - e^{\frac{-\nu R\&D_{i,t}}{\Phi_{k,t} P_{k,t}}} \tag{20}$$

where $P_{k,t}$ and $\Phi_{k,t}$ are the average price and the average labor productivity of firms operating in the same country.
When successful in innovating, firms update their labor productivity as shown in 21:

$$\phi_{i,t+1} = \phi_{i,t}(1 + U[0, \delta]) \tag{21}$$

Innovation Activities II

Firms having a level of productivity below the average can exploit **sectoral spillovers** to catch up. If successful, they sample a new productivity level in a range between their current one and the sector average.

$$\phi_{i,t+1} = \phi_{i,t} + U[0, (\Phi_t^X - \phi_{i,t})] \ \textit{if} \ \phi_{i,t} < \Phi_t^X \tag{22}$$

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