Monetary Policy and Sectoral Composition

Cesar Blanco – Central Bank of Paraguay
Sebastian Diz – Central Bank of Paraguay

XXIV Reunion de la Red de Investigadores de Banca Central – CEMLA
Oct 30–31, 2019
Introduction
Introduction

• Objective of central banks: stabilize inflation.
  ◦ For this purpose they define the measure of inflation to target.

• Two measures commonly targeted:
  ◦ Core inflation: excludes volatile agricultural and energy prices.
  ◦ Headline inflation: weighted average of inflation across sectors.

• It has been argued that core inflation is the optimal measure to target (Mishkin, 2008; Wynne, 2008; Bodenstein et al., 2008)
  ◦ Excluding volatile agricultural prices minimizes welfare loss.

• Should central banks in developing countries, where the agricultural sector is large, also exclude agricultural prices from their target?
- Countries in an early stage of development have a large concentration of economic activity in agriculture (Herrendorf et al., 2014)
  - Low income elasticity $\rightarrow$ Low income implies high share of agricultural consumption in total expenditures.
  - Low price elasticity $\rightarrow$ Low agricultural productivity implies high share of employment in this sector.

- Distinctive features of agriculture:
  - Agricultural prices are flexible (Bils and Klenow, 2004).
  - Productivity shocks specific to agriculture.
  - Shocks in agriculture are less persistent and more volatile than in non-agriculture (Anad et al., 2015).
Aim

- What is the optimal weight that a central bank in a developing country should assign to agricultural and non-agricultural inflation?

- Is this weight affected by the sectoral composition of an economy?
Approach

- We consider a multi-sector NK model including nominal price and wage rigidities and features from the structural change literature.

- Calibrate the model to match the sectoral composition of developing and developed countries.

- We use a Taylor–rule with different weights on agricultural and non-agricultural inflation.

- Evaluate welfare losses after sector-specific productivity shocks.

- Compute the weight in the Taylor-rule that minimizes welfare loss.

- Derive a welfare loss function analytically to find the factors that explain welfare loss.
Aoki (2001): Stabilizing sticky price inflation is sufficient to stabilize inflation level around its efficient level.

Mankiw and Reis (2003): Central banks should weight a sector in the price index given its characteristics: price stickiness, size, cyclical sensitivity and magnitude of sectoral shock.

Anad et al. (2015): They consider segmented labor markets and hand-to-mouth consumers and find that central banks should include agricultural prices in the target.

Portillo et al. (2016): Target core inflation only. Losses from missing this target are larger for countries where subsistence requirements are larger.
Outline

1. Introduction

2. Model

3. Results
   - Optimal measure in developing countries
   - Optimal measure in developed countries
   - Welfare implications
   - Role of sticky wages

4. Conclusion
Model
## The model

<table>
<thead>
<tr>
<th>Standard</th>
<th>NK model (EHL, 2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sectors</td>
<td>Agriculture and non-agriculture, $s = {a, n}$</td>
</tr>
<tr>
<td>Preferences</td>
<td>Non-unitary income elasticity in agriculture</td>
</tr>
<tr>
<td></td>
<td>Non-unitary price-elasticity</td>
</tr>
<tr>
<td>Technology</td>
<td>Sector specific exogenous productivity shocks</td>
</tr>
<tr>
<td>Nominal rigidities</td>
<td>Non-agricultural prices and wages</td>
</tr>
<tr>
<td></td>
<td>Calvo pricing</td>
</tr>
</tbody>
</table>
The model

Taylor rule
\[ R_t = \frac{1}{\beta} \left( \frac{\Pi^*_t}{\Pi} \right)^{\phi} \]

Measure of inflation
\[ \Pi^*_t = \Pi_{\Omega,t}^{\Omega} \Pi_{n,t}^{1-\Omega} \]

Shocks
\[ A_{s,t} = A_{s,0} e^{a_{s,t}} \]
\[ a_{s,t} = \rho_s a_{s,t-1} + \nu_{s,t} \]

Welfare
Aggregate of households’ utility

Optimal Ω
Welfare loss is minimized
Results
Results: optimal $\Omega$ in developing country

(a) Shock A: $\Omega_{opt} = 0$

(b) Shock NA: $\Omega_{opt} = 1$

(c) Both shocks: $\Omega_{opt} = 0.8$
IR: shock A in developing country

Blue line: headline infl. targeting ($\Omega = 0.35$). Red dashed line: core infl. targeting ($\Omega = 0$).
IR: shock NA in developing country

Blue line: headline infl. targeting ($\Omega = 0.35$). Red dashed line: core infl. targeting ($\Omega = 0$).
Intuition

Flexible agricultural prices:

\[ P_{a,t} = \mu_p \frac{W_t}{A_{a,0}} \]

Sticky non-agricultural prices:

\[ P_{n,t}^* = \mu_p \frac{\sum_{k=0}^{\infty} \theta_n^k E_t \left\{ Q_{t,t+k} Y_{n,t+k} | t \frac{W_{t+k}}{A_{n,t+k}} \right\}}{\sum_{k=0}^{\infty} \theta_n^k E_t \left\{ Q_{t,t+k} Y_{n,t+k} | t \right\}} \]

**Targeting agricultural inflation**

⇒ affects wage inflation
⇒ affects non-agricultural price inflation (indirectly)
⇒ these are the main source of welfare loss
Results: optimal $\Omega$ in developed country

(a) Shock A: $\Omega^{opt} = 0$

(b) Shock NA: $\Omega^{opt} = 1$

(c) Both shocks: $\Omega^{opt} = 0.8$
Intuition: rich vs poor economies ($\Omega = 1$)

Continuous line: rich country ($N_a/N = 0.02$). Dashed: poor country ($N_a/N = .3$). Dashed and dotted: poor country ($N_a/N = .5$).
Sectoral composition and welfare gains

(a) Developing country (shock n)

(b) Rich country (shock n)

(c) Developing country (shock a)

(d) Rich country (shock a)
Role of sticky wages

- Setting $\Omega = 1$ after shock $n$ is optimal.
  - Reason: link between agricultural inflation and wage inflation
- Robust to changes in sectoral composition but not to changes in $\theta_w$
  - In fact, as $\theta_w \rightarrow 0 \Rightarrow \Omega^{opt}$ declines

- Modified Taylor–rule

$$R_t = \frac{1}{\beta} \left( \frac{\Pi^*_t}{\Pi} \right)^{\phi_n} \left( \frac{\Pi_{w,t}}{\Pi_w} \right)^{\phi_w}$$

**Result:**

⇒ For $\phi_w \geq 3$, $\Omega^{opt}$ close to zero.
⇒ Targeting agricultural price inflation is a proxy for targeting wage inflation.
## Welfare loss function

<table>
<thead>
<tr>
<th>Welfare loss</th>
<th>Developing country</th>
<th>Rich country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Omega = 0$</td>
<td>$\Omega = 1$</td>
</tr>
<tr>
<td>$\tilde{y}^2_a$</td>
<td>0.0215</td>
<td>0.000</td>
</tr>
<tr>
<td>$\tilde{y}^2_n$</td>
<td>1.6828</td>
<td>1.0881</td>
</tr>
<tr>
<td>$\tilde{\pi}^2_a$</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
<tr>
<td>$\tilde{\pi}^2_n$</td>
<td>6.3878</td>
<td>3.4677</td>
</tr>
<tr>
<td>$\tilde{\pi}^2_w$</td>
<td>36.8258</td>
<td>0.0230</td>
</tr>
<tr>
<td>Total</td>
<td>44.9181</td>
<td>4.7589</td>
</tr>
</tbody>
</table>

- Wage inflation has the largest weight on welfare loss, followed by non-agricultural price inflation.
- Fully targeting agricultural inflation minimizes welfare loss.
Conclusion
Conclusion

- Targeting agricultural inflation can minimize welfare loss. For this results we only need to consider sticky wages, as opposed to Anad et al. (2015) who consider segmented labor markets and incomplete financial markets.

- Sectoral composition affects the welfare gain obtained from targeting the correct measure of inflation. Developed countries experience larger welfare gains by targeting agricultural inflation after non-agricultural shocks.

- Targeting agricultural prices is a proxy for targeting wage inflation.

- Future work:
  - Different degree of wage stickiness across sectors
  - Imperfect labor mobility
  - Structure of the shock in developing countries
Thank you!
Preferences

- There is a continuum of households indexed by $j \in [0, 1]$ with utility

$$E_0 \left\{ \beta^t \sum_{t=0}^{\infty} \left( \frac{C_t(j)^{1-\sigma}}{1-\sigma} - \frac{N_t(j)^{1+\phi}}{1+\phi} \right) \right\}$$

where

$$C_t(j) \equiv \left( \frac{1}{\gamma} (C_{a,t}(j) - \bar{C}_a)^{\gamma - 1} + \omega_n C_{n,t}(j)^{\gamma - 1} \right)^{\frac{\gamma}{\gamma - 1}}$$

and

$$C_{s,t}(j) \equiv \left( \int_0^1 C_{s,t}(i,j)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} di \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$
Intra–temporal optimization

- Household $j$ consumption demand for variety $i$ satisfies
  \[ C_{s,t}(i,j) = \left( \frac{P_{s,t}(i)}{P_{s,t}} \right)^{-\varepsilon_p} C_{s,t}(j) \]

  and sectoral demands are given by
  \[ C_{a,t}(j) = \tilde{C}_a + \omega_a \left( \frac{P_{a,t}}{P_t} \right)^{-\gamma} C_t(j) \]

  and
  \[ C_{n,t}(j) = \omega_n \left( \frac{P_{n,t}}{P_t} \right)^{-\gamma} C_t(j) \]

  where the prices are defined as
  \[ P_{s,t} \equiv \left( \int_0^1 P_{s,t}^{1-\varepsilon_p} \, di \right)^{\frac{1}{1-\varepsilon_p}} \text{ and } P_t \equiv \left( \omega_a P_{a,t}^{1-\gamma} + \omega_n P_{n,t}^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \]
• The budget constraint of household $j$:

$$
\int_{0}^{1} P_{a,t}(i)C_{a,t}(i,j)di + \int_{0}^{1} P_{n,t}(i)C_{n,t}(i,j)di + Q_{t}B_{t}(j) = W_{t}(j)N_{t}(j) + B_{t-1}(j) + \Pi_{t}(j)
$$

• From the intra-temporal optimality conditions

$$
P_{t}C_{t} + Q_{t}B_{t}(j) = W_{t}(j)N_{t}(j) + B_{t-1}(j) + \Pi_{t}(j) - P_{a,t}\tilde{C}_{a,t}
$$
Optimal wage setting

- In every period households reset wages with probability \( (1 - \theta_w) \). Households maximize

\[
\max_{W_t^*} E_t \sum_{t=0}^{\infty} (\theta_w/\beta)^k \left[ \frac{C_{t+k|k}^{1-\sigma}}{1-\sigma} - \frac{N_{t+k|k}^{1+\phi}}{1+\phi} \right]
\]

s.t. labor demand \( N_{t+k|k} = \left( \frac{W_{t+k}}{W_{t+k}} \right)^{-\varepsilon_w} N_{t+k} \) and the budget constraint.

- Optimization implies

\[
\sum_{t=0}^{\infty} (\theta_w/\beta)^k E_t \left\{ C_{t+k|k}^{1-\sigma} N_{t+k|k} \left[ \frac{W_{t+k}}{P_{t+k}} - \mu_w MRS_{t+k|t} \right] \right\}
\]

where \( \mu_w \) is the markup and if \( \theta_w = 0 \) the \( \frac{W_t}{P_t} = \mu_w MRS_t \).
As in Erceg, Hernderson and Levin (2000) we assume complete assets markets. Inter–temporal optimization implies the following Euler equation

\[ Q_t = \mathbb{E}_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \]
Firms

• In each sector $s \in \{a, n\}$ there is a continuum of firms indexed by $i \in [0, 1]$.
• Production is given by: $Y_{s,t}(i) = A_{s,t} N_{s,t}(i)^{1-\alpha_s}$ where productivity $A_{s,t}$ is common to firms in the same sector.
• $N_{s,t}(i)$ is an index of labor inputs

$$N_{s,t}(i) = \int_0^1 \left( N_{s,t}(i,j) \frac{\varepsilon_w-1}{\varepsilon_w} d j \right)^{\frac{\varepsilon_w}{\varepsilon_w-1}}$$

where $N_{s,t}(i,j)$ is labor variety $j \in [0, 1]$.
• Labor demand is given by:

$$N_{s,t}(i,j) = \left( \frac{W_t(j)}{W_t} \right)^{-\varepsilon_w} N_{s,t}(i)$$

where the wage index $W_t \equiv \int_0^1 \left( W_t(j)^{1-\varepsilon_w} d j \right)^{\frac{1}{1-\varepsilon_w}}$. 
Optimal price setting

- In every period, firms in sector $s$ reset prices with probability $(1 - \theta_s)$: Firms maximize

$$\max_{P^*_{s,t}} \sum_{k=0}^{\infty} (\theta_s)^k E_t \left\{ Q_{t,t+k} [P^*_{s,t} Y_{s,t+k|k} - TC_{t+k}(Y_{s,t+k|k})] \right\}$$

s.t. labor demand $Y_{s,t+k|k} = \left( \frac{P^*_{s,t}}{P_{s,t+k}} - \epsilon_p \right) C_{s,t+k}$ and a budget constraint.

- Optimization implies:

$$\sum_{k=0}^{\infty} (\theta_s)^k E_t \left\{ Q_{t,t+k} Y_{s,t+k|k} [P^*_{s,t} - \mu_p MC^n_{s,t+k}] \right\} = 0$$

where $\mu_p$ is the mark-up and if $\theta_s = 0$ we have that $P_{s,t} = \mu_p MC^n_{s,t}$. 
Prices and wages are given by

\[ P_{s,t}^{1-\varepsilon_p} = \theta_a P_{s,t-1}^{1-\varepsilon_p} + (1 - \theta_a) P_{s,t}^{*1-\varepsilon_p} \]

and

\[ W_t^{1-\varepsilon_w} = \theta_w W_{t-1}^{1-\varepsilon_w} + (1 - \theta_w) W_t^{*1-\varepsilon_w} \]
Market clearing and aggregation

- Goods market clearing implies: \( Y_{s,t} = C_{s,t} \).
- Output in sector \( s \) is given by
  \[
  Y_{s,t} = A_{s,t} N_{s,t}^{1-\alpha_s} (\Delta_{w,t} \Delta_{p,t}^s)^{-1}(1-\alpha_s)
  \]
  where price and wage dispersion defined as
  \[
  \Delta_{w,t} \equiv \int_0^1 (W_t(j)/W_t)^{-\varepsilon_w} dj \quad \text{and} \quad \Delta_{p,t}^s \equiv \int_0^1 (P_s(t(i)/P_s,t)_{1-\alpha_s} - \alpha_s) di
  \]
  are sources of inefficient output and employment variation due to inefficient price and wage dispersion.
- Labor market clearing implies: \( N_{s,t} = \int_0^1 \int_0^1 N_s(t(i,j))djdi \).
- Aggregate output:
  \[
  Y = \frac{P_{a,t}}{P_t} Y_{a,t} + \frac{P_{n,t}}{P_t} Y_{n,t} = C_t + \frac{P_{a,t}}{P_t} \tilde{C}_a
  \]
Central bank

- The central bank follows a simple and implementable Taylor–rule as

\[ R_t = \frac{1}{\beta} \left( \frac{\Pi^*_t}{\Pi} \right)^{\phi_\pi} \]

where \( R_t \equiv 1/Q_t \), \( \phi_\pi > 1 \) is the weight assigned to inflation with respect to steady state.

- The inflation target is defined as

\[ \Pi^*_t = \Pi_{a,t}^\Omega \Pi_{n,t}^{1-\Omega} \]

where \( \Omega \) is the weight assigned to agricultural inflation.

- When \( \Omega = 0 \), the target is core inflation, when \( \Omega = PaCa/PY \) the target is headline inflation.
Welfare of household $j$ can be expressed recursively as

$$\mathbb{W}_t(j) = \frac{C_t(j)^{1-\sigma}}{1-\sigma} - \frac{N_t(j)^{1+\phi}}{1+\phi} + \beta \mathbb{E}_t\{\mathbb{W}_{t+1}(j)\}$$

Aggregating welfare for all households and assuming complete assets markets ($C_t(j) = C_t$)

$$\int_0^1 \mathbb{W}_t(j) dj = \frac{C_t^{1-\sigma}}{1-\sigma} - \int_0^1 \frac{N_t(j)^{1+\phi}}{1+\phi} di + \beta \mathbb{E}_t \int_0^1 \mathbb{W}_{t+1}(j) dj$$

Using $N_t(j) = (W_t(j)/W_t)^{-\varepsilon} N_t$ we have

$$\mathbb{W}_t = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} \Delta_{w,t}^* + \beta \mathbb{E}_t\{\mathbb{W}_{t+1}\}$$

where $\mathbb{W}_t \equiv \int_0^1 \mathbb{W}_t(j)$ and $\Delta_{w,t}^* \equiv \int_0^1 (W_t(j)/W_t)^{-\varepsilon}(1+\phi) dj$ reflect inefficient employment variation due to inefficient wage dispersion.
## Parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega_a$</td>
<td>Weight of agr. in utility in rich countries</td>
<td>0.02</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Elasticity of subs. between agr. and non–agr.</td>
<td>0.03</td>
</tr>
<tr>
<td>$\tilde{C}_a$</td>
<td>Employment in agr. in developing countries (30%)</td>
<td>0.02808</td>
</tr>
<tr>
<td>$A_n$</td>
<td>Income of developing country (15% of US)</td>
<td>0.1284</td>
</tr>
<tr>
<td>$A_a$</td>
<td>Relative agr. price in developing country (1.5 of US)</td>
<td>$0.66A_n$</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Inter–temporal elasticity of substitution</td>
<td>1</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>Inverse of the Frisch elasticity of labor supply</td>
<td>1</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.99</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>Autocorr. of shock a</td>
<td>0.25</td>
</tr>
<tr>
<td>$\rho_n$</td>
<td>Autocorr. of shock n</td>
<td>0.9</td>
</tr>
<tr>
<td>$\sigma_{va}$</td>
<td>Std. dev. of shock a</td>
<td>0.03</td>
</tr>
<tr>
<td>$\sigma_{vn}$</td>
<td>Std. dev. of shock n</td>
<td>0.02</td>
</tr>
<tr>
<td>$\varepsilon_p$</td>
<td>Elast. of subs. across goods varieties</td>
<td>6</td>
</tr>
<tr>
<td>$\varepsilon_w$</td>
<td>Elast. of subs. across labor varieties</td>
<td>6</td>
</tr>
<tr>
<td>$\theta_a$</td>
<td>Prob of not resetting prices in sector a</td>
<td>0</td>
</tr>
<tr>
<td>$\theta_n$</td>
<td>Prob of not resetting prices in sector n</td>
<td>2/3</td>
</tr>
<tr>
<td>$\theta_w$</td>
<td>Prob of not resetting wages</td>
<td>3/4</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>Weight assigned to price inflation</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Sensitivity analysis

- Changes in parameters that affect the steady state of the model:
  - No effects on optimal $\Omega$.

- Changes in productivity shock parameters:
  - Higher weight to agricultural inflation when shocks to this sector are less persistent and of less magnitude than in non-agriculture.

- Flexible wages ($\theta_w = 0$):
  - As the welfare loss due to wage dispersion is reduced, the optimal weight of wage inflation is close to zero.
Welfare: fraction of consumption.

Aggregate welfare:

\[ W_t = \int_0^1 W_t(j)\,dj = E_t \sum_{k=0}^{\infty} \beta^k \ln C_{t+k} - E_t \sum_{k=0}^{\infty} \beta^k \frac{N_{t+k}^{1+\varphi}}{1+\varphi} \int_0^1 \left( \frac{W_t(j)}{W_t} \right)^{-\varepsilon_p(1+\varphi)} \,dj \]

For policy \( z_1 \) (i.e: core or headline inflation targeting):

\[ W_{z_1, t} = E_t \sum_{k=0}^{\infty} \beta^k \ln C_{z_1, t+k} - \Psi_{z_1, t} \]

We define \( \lambda \) as the fraction of additional consumption that would make households as well off under policy \( z_2 \) as under policy \( z_1 \)

\[ W_{z_2, t} = E_t \sum_{k=0}^{\infty} \beta^k \ln \left[ (1 + \lambda) C_{z_1, t+k} \right] - \Psi_{z_1, t} \]

\[ = E_t \sum_{k=0}^{\infty} \beta^k \ln (1 + \lambda) + W_{z_1, t} \]

\[ \lambda = \exp \left[ (1 - \beta) (W_{z_2, t} - W_{z_1, t}) \right] - 1 \]

Using Figure 2.11:

(a) Developing country after shock in \( n \) (optimal weight vs headline): \( \lambda = 0.1503 \)
(b) Rich country after shock in \( n \) (optimal weight vs headline): \( \lambda = 0.2969 \)
(c) Developing country after shock in \( a \) (core vs headline): \( \lambda = 0.0110 \)
(d) Rich country after shock in \( a \) (core vs headline): \( \lambda = 0.0009 \)
Welfare loss function

- To analyze the factors that explain of welfare loss we derive an analytical welfare loss function.
- We simplify the model and consider only non–agricultural shocks and Cobb-Douglas preferences ($\gamma = 1$).

\[
W = - \frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \psi_{ya} \tilde{y}_{a,t}^2 + \psi_{yn} \tilde{y}_{n,t}^2 \\
+ \psi_p (\tilde{p}_{a,t} - \tilde{p}_{n,t})^2 + \psi_{\pi_a} \pi_{a,t}^2 + \psi_{\pi_n} \pi_{n,t}^2 + \psi_{\pi_w} \pi_{w,t}^2 \right]
\]