The Optimal Inflation Rate under Downward Nominal Wage Rigidity

Mikael Carlsson and Andreas Westermark

SVERIGES RIKSBANK

Introduction/Motivation

- Puzzle introduced by Schmitt-Grohe & Uribe (2010): Cannot generate a significant positive Ramsey optimal inflation rate in standard monetary models, whereas central banks typically target 2% inflation.
- Tobin (1972): Inflation grease the wheels when wages cannot be adjusted downward.

Introduction/Motivation

- Puzzle introduced by Schmitt-Grohe & Uribe (2010): Cannot generate a significant positive Ramsey optimal inflation rate in standard monetary models, whereas central banks typically target 2% inflation.
- Tobin (1972): Inflation grease the wheels when wages cannot be adjusted downward.

- Robust empirical finding: Money wages do not fall during an economic downturn.
  - Data from personnel files: Altonji & Devereux (2000), Baker, Gibbs & Holmstrom (1994), Fehr & Goette (2005), and Wilson (1999).
  - Survey/register data in Altonji & Devereux (2000), Akerlof, Dickens & Perry (1996), Dickens et. al. (2007), Fehr & Goette (2005), Holden & Wulfsberg (2008) and others.
  - Interviews or surveys with wage setters like Agell & Lundborg (2003), and Bewley (1999).

- Robust empirical finding: Money wages do not fall during an economic downturn.
  - Data from personnel files: Altonji & Devereux (2000), Baker et al. (1994), Fehr & Goette (2005), and Wilson (1999).
  - Survey/register data in Altonji & Devereux (2000), Akerlof et al. (1996), Dickens et. al. (2007), Fehr & Goette (2005), Holden & Wulfsberg (2008) and others.
  - Interviews or surveys with wage setters like Agell & Lundborg (2003), and Bewley (1999).

- Robust empirical finding: Money wages do not fall during an economic downturn.
  - Data from personnel files: Altonji & Devereux (2000), Baker et al. (1994), Fehr & Goette (2005), and Wilson (1999).
  - Survey/register data in Altonji & Devereux (2000), Akerlof et al. (1996), Dickens et. al. (2007), Fehr & Goette (2005), Holden & Wulfsberg (2008) and others.
  - Interviews or surveys with wage setters like Agell & Lundborg (2003), and Bewley (1999).

- Robust empirical finding: Money wages do not fall during an economic downturn.
  - Data from personnel files: Altonji & Devereux (2000), Baker et al. (1994), Fehr & Goette (2005), and Wilson (1999).
  - Survey/register data in Altonji & Devereux (2000), Akerlof et al. (1996), Dickens et. al. (2007), Fehr & Goette (2005), Holden & Wulfsberg (2008) and others.
  - Interviews or surveys with wage setters like Agell & Lundborg (2003), and Bewley (1999).

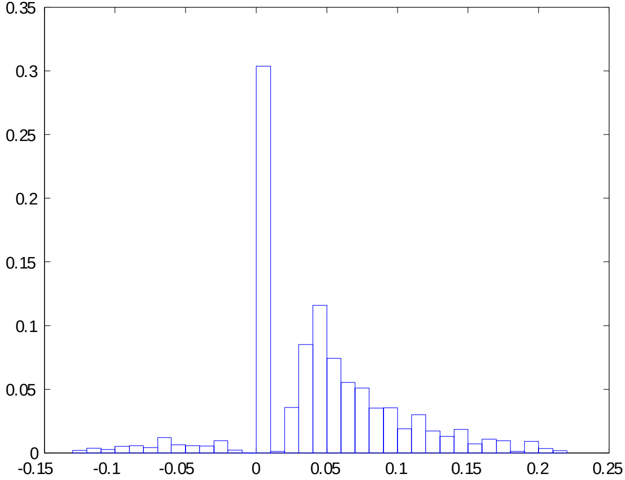


Figure: Empirical distribution of yearly nominal wage changes for stayers in the US during the period 1993-1997 (PSID, cleaned from measurement error)

- Economic consequences:
  - Real wages might be too high for some firms, leading to too much unemployment.
  - Asymmetric dynamics.
  - Inflation leads to decrease in real wages for firms that don't renegotiate wages.

- Economic consequences:
  - Real wages might be too high for some firms, leading to too much unemployment.
  - Asymmetric dynamics.
  - Inflation leads to decrease in real wages for firms that don't renegotiate wages.

- Economic consequences:
  - Real wages might be too high for some firms, leading to too much unemployment.
  - Asymmetric dynamics.
  - Inflation leads to decrease in real wages for firms that don't renegotiate wages.

- Economic consequences:
  - Real wages might be too high for some firms, leading to too much unemployment.
  - Asymmetric dynamics.
  - Inflation leads to decrease in real wages for firms that don’t renegotiate wages.

Related literature

- Kim & Ruge-Murcia (2010)
- Fagan & Messina (2009)

Related literature

- Kim & Ruge-Murcia (2010)
- Fagan & Messina (2009)

Purpose

- The purpose of this paper is to study the implications for monetary policy in terms of optimal average inflation when:
  - There is a role for money as a medium of exchange.
  - Declining nominal wages might not be a viable margin for adjustment.
  - State dependent price/wage setting - Lucas critique.
  - Deterministic aggregate productivity growth - important, since it pushes optimal inflation down substantially.
  - Stochastic idiosyncratic productivity to match the empirical wage change distribution.

Purpose

- The purpose of this paper is to study the implications for monetary policy in terms of optimal average inflation when:
    - There is a role for money as a medium of exchange.
    - Declining nominal wages might not be a viable margin for adjustment.
    - State dependent price/wage setting - Lucas critique.
    - Deterministic aggregate productivity growth - important, since it pushes optimal inflation down substantially.
    - Stochastic idiosyncratic productivity to match the empirical wage change distribution.

Purpose

- The purpose of this paper is to study the implications for monetary policy in terms of optimal average inflation when:
  - There is a role for money as a medium of exchange.
  - Declining nominal wages might not be a viable margin for adjustment.
  - State dependent price/wage setting - Lucas critique.
  - Deterministic aggregate productivity growth - important, since it pushes optimal inflation down substantially.
  - Stochastic idiosyncratic productivity to match the empirical wage change distribution.

Purpose

- The purpose of this paper is to study the implications for monetary policy in terms of optimal average inflation when:
  - There is a role for money as a medium of exchange.
  - Declining nominal wages might not be a viable margin for adjustment.
  - State dependent price/wage setting - Lucas critique.
  - Deterministic aggregate productivity growth - important, since it pushes optimal inflation down substantially.
  - Stochastic idiosyncratic productivity to match the empirical wage change distribution.

Purpose

- The purpose of this paper is to study the implications for monetary policy in terms of optimal average inflation when:
  - There is a role for money as a medium of exchange.
  - Declining nominal wages might not be a viable margin for adjustment.
  - State dependent price/wage setting - Lucas critique.
  - Deterministic aggregate productivity growth - important, since it pushes optimal inflation down substantially.
  - Stochastic idiosyncratic productivity to match the empirical wage change distribution.

Purpose

- The purpose of this paper is to study the implications for monetary policy in terms of optimal average inflation when:
  - There is a role for money as a medium of exchange.
  - Declining nominal wages might not be a viable margin for adjustment.
  - State dependent price/wage setting - Lucas critique.
  - Deterministic aggregate productivity growth - important, since it pushes optimal inflation down substantially.
  - Stochastic idiosyncratic productivity to match the empirical wage change distribution.

Overview

1. The model.
2. (Ramsey policy)
3. Calibration.
4. Numerical results.

Overview

1. The model.
2. (Ramsey policy)
3. Calibration.
4. Numerical results.

Overview

1. The model.
2. (Ramsey policy)
3. Calibration.
4. Numerical results.

Overview

1. The model.
2. (Ramsey policy)
3. Calibration.
4. Numerical results.

The Economic Environment

Intermediate-goods Firms, Prices and Wages

- State dependent price setting as in Dotsey, King & Wolman (1999) and Lie (2010).
- Menu cost c_p of changing prices. Follows cdf G_P.
- Let α_t^j denote the endogenous probability of adjusting prices in period t, given that the firm last adjusted it's price j periods ago.
- There is $J > 1$ such that $\alpha^J = 1$.

The Economic Environment

Intermediate-goods Firms, Prices and Wages

- State dependent price setting as in Dotsey et al. (1999) and Lie (2010).
- Menu cost c_p of changing prices. Follows cdf G_P.
- Let α_t^j denote the endogenous probability of adjusting prices in period t, given that the firm last adjusted it's price j periods ago.
- There is $J > 1$ such that $\alpha^J = 1$.

The Economic Environment
Intermediate-goods Firms, Prices and Wages

- State dependent price setting as in Dotsey et al. (1999) and Lie (2010).
- Menu cost c_p of changing prices. Follows cdf G_P.
- Let α_t^j denote the endogenous probability of adjusting prices in period t, given that the firm last adjusted it's price j periods ago.
- There is $J > 1$ such that $\alpha^J = 1$.

The Economic Environment

Intermediate-goods Firms, Prices and Wages

- State dependent price setting as in Dotsey et al. (1999) and Lie (2010).
- Menu cost c_p of changing prices. Follows cdf G_P.
- Let α_t^j denote the endogenous probability of adjusting prices in period t, given that the firm last adjusted it's price j periods ago.
- There is $J > 1$ such that $\alpha^J = 1$.

- Firms faces demand

$$Y_t^j = \left(\frac{P_t^j}{P_t}\right)^{-\sigma} Y_t, \qquad (1)$$

and uses a wholesale good as input. The wholesale sector is perfectly competitive where the market price is denoted by p_t^w.

- The price is chosen such that

$$\begin{aligned} v_t^0 &= \max_{P_t^0} \left[\frac{P_t^0}{P_t} - p_t^w\right] Y_t^0 \\ &+E_t \Lambda_{t,t+1} \beta \left(\alpha_{t+1}^1 v_{t+1}^0 + \left(1-\alpha_{t+1}^1\right) v_{t+1}^1 \left(\frac{P_t^0}{P_{t+1}}\right)\right) \\ &-E_t \Lambda_{t,t+1} \beta p_{t+1}^w \alpha_{t+1}^1 \Xi_{1,t+1}, \end{aligned} \qquad (2)$$

where $\alpha_{t+1}^1 \Xi_{1,t+1}$ is expected price adjustment costs $\Lambda_{t,t+1}$ is the ratio of Lagrange multipliers for consumers.

- Firms faces demand

$$Y_t^j = \left(\frac{P_t^j}{P_t}\right)^{-\sigma} Y_t, \tag{1}$$

and uses a wholesale good as input. The wholesale sector is perfectly competitive where the market price is denoted by p_t^w.

- The price is chosen such that

$$\begin{aligned} v_t^0 &= \max_{P_t^0} \left[\frac{P_t^0}{P_t} - p_t^w\right] Y_t^0 \\ &+E_t\Lambda_{t,t+1}\beta\left(\alpha_{t+1}^1 v_{t+1}^0 + \left(1-\alpha_{t+1}^1\right) v_{t+1}^1\left(\frac{P_t^0}{P_{t+1}}\right)\right) \\ &-E_t\Lambda_{t,t+1}\beta p_{t+1}^w \alpha_{t+1}^1 \Xi_{1,t+1}, \end{aligned} \tag{2}$$

where $\alpha_{t+1}^1 \Xi_{1,t+1}$ is expected price adjustment costs $\Lambda_{t,t+1}$ is the ratio of Lagrange multipliers for consumers.

and

$$\Xi_{j,t} = \frac{1}{\alpha_t^j} \int_0^{G_P^{-1}\left(\alpha_t^j\right)} x dG_P(x).$$

- The values v_t^j evolve according to

$$\begin{aligned} v_t^j\left(\frac{P_t^j}{P_t}\right) &= \left[\frac{P_t^j}{P_t} - p_t^w\right] Y_t^j \\ &\quad + E_t \Lambda_{t,t+1} \beta \left(\alpha_{t+1}^{j+1} v_{t+1}^0 + \left(1-\alpha_{t+1}^{j+1}\right) v_{t+1}^{j+1}\left(\frac{P_t^j}{P_{t+1}}\right)\right) \\ &\quad - E_t \Lambda_{t,t+1} \beta p_{t+1}^w \alpha_{t+1}^{j+1} \Xi_{j+1,t+1}. \end{aligned}$$

- Price adjustment probabilities are

$$\alpha_t^j = G_P\left(\frac{v_t^0 - v_t^j}{p_t^w}\right).$$

Households

- Consumption purchases are subject to a proportional transaction cost as in Schmitt-Grohe & Uribe (2004).
- Payoff function

$$E_t \sum_{r=t}^{\infty} \beta^{r-t} \left[u(c_r) - \int_i \kappa^L \frac{(h_{ir})^{1+\xi}}{1+\xi} di \right]. \quad (3)$$

- Given consumption c_t and price level P_t total consumption cost is

$$P_t c_t \left(1 + s \left(\frac{c_t}{m_t} \right) \right)$$

where P_t is the price level, m_t is real balances and

$$s = A \frac{c_t}{m_t} + B \frac{m_t}{c_t} - 2\sqrt{AB}.$$

Households

- Consumption purchases are subject to a proportional transaction cost as in Schmitt-Grohe & Uribe (2004).
- Payoff function

$$E_t \sum_{r=t}^{\infty} \beta^{r-t} \left[u\left(c_r\right) - \int_i \kappa^L \frac{\left(h_{ir}\right)^{1+\xi}}{1+\xi} di \right]. \tag{3}$$

- Given consumption c_t and price level P_t total consumption cost is

$$P_t c_t \left(1 + s\left(\frac{c_t}{m_t}\right)\right)$$

where P_t is the price level, m_t is real balances and

$$s = A\frac{c_t}{m_t} + B\frac{m_t}{c_t} - 2\sqrt{AB}.$$

Households

- Consumption purchases are subject to a proportional transaction cost as in Schmitt-Grohe & Uribe (2004).
- Payoff function

$$E_t \sum_{r=t}^{\infty} \beta^{r-t} \left[u\left(c_r\right) - \int_i \kappa^L \frac{\left(h_{ir}\right)^{1+\xi}}{1+\xi} di \right]. \tag{3}$$

- Given consumption c_t and price level P_t total consumption cost is

$$P_t c_t \left(1 + s\left(\frac{c_t}{m_t}\right)\right)$$

where P_t is the price level, m_t is real balances and

$$s = A\frac{c_t}{m_t} + B\frac{m_t}{c_t} - 2\sqrt{AB}.$$

- The budget constraint is given by

$$P_t c_t \left(1 + s\left(\frac{c_t}{m_t}\right)\right) + P_t m_t + \frac{b_t}{R_t} + \theta_{t+1} P_t \left(F_t - Z_t\right)$$
$$\geq \quad P_{t-1} m_{t-1} + \varpi_t + \mathcal{W}_t,$$

- where b_t is bonds R_t the interest rate, θ_{t+1} is the share of intermediate product firms F_t, the value of firms and Z_t dividends.
- ϖ_t is wealth at the start of time and

$$\mathcal{W}_t = \int_0^1 E_t W_{it} di + (1 - n_t)\, b_r,$$

where b_r representing the value of home production.

- The budget constraint is given by

$$
\begin{aligned}
& P_t c_t \left(1 + s\left(\frac{c_t}{m_t}\right)\right) + P_t m_t + \frac{b_t}{R_t} + \theta_{t+1} P_t \left(F_t - Z_t\right) \\
\geq \quad & P_{t-1} m_{t-1} + \varpi_t + \mathcal{W}_t,
\end{aligned}
$$

- where b_t is bonds R_t the interest rate, θ_{t+1} is the share of intermediate product firms F_t, the value of firms and Z_t dividends.
- ϖ_t is wealth at the start of time and

$$
\mathcal{W}_t = \int_0^1 E_t W_{it} di + \left(1 - n_t\right) b_r,
$$

where b_r representing the value of home production.

- The budget constraint is given by

$$\begin{aligned} & P_t c_t \left(1 + s\left(\frac{c_t}{m_t}\right)\right) + P_t m_t + \frac{b_t}{R_t} + \theta_{t+1} P_t \left(F_t - Z_t\right) \\ \geq \quad & P_{t-1} m_{t-1} + \varpi_t + \mathcal{W}_t, \end{aligned}$$

- where b_t is bonds R_t the interest rate, θ_{t+1} is the share of intermediate product firms F_t, the value of firms and Z_t dividends.
- ϖ_t is wealth at the start of time and

$$\mathcal{W}_t = \int_0^1 E_t W_{it} di + (1 - n_t)\, b_r,$$

where b_r representing the value of home production.

Labor market I - production and matching

- Several wholesale firms with one employee that sell a good y_{it} produced using labor (hours) h_{it} given productivity a_{it} to intermediate goods firms with technology

$$y_{it} = (a_{it}h_{it})^{1-\gamma}.$$

where

$$a_{it} = e^{\gamma_r t}\varepsilon_{it}^{a}$$

with γ_r the growth rate of aggregate productivity and ε_{it}^{a} an idiosyncratic shock.

- Matches separate with probability $1 - \rho$.
- Constant-returns matching function

$$m_t^a = \sigma_m u_t^{\sigma_a} v_t^{1-\sigma_a},$$

where

$$u_t = 1 - n_t.$$

and v_t is aggregate vacancies.

- Matches separate with probability $1 - \rho$.
- Constant-returns matching function

$$m_t^a = \sigma_m u_t^{\sigma_a} v_t^{1-\sigma_a},$$

where

$$u_t = 1 - n_t.$$

and v_t is aggregate vacancies.

Labor market II - Wage determination

- Wholesale firms and workers adjust wages with some positive endogenously determined probability $\alpha_t^{j_w}$ in the j_w'th period following the last renegotiation (state dependent).
- Note that $\alpha_t^{J_w} = 1$ for some $J_w > 1$.

Labor market II - Wage determination

- Wholesale firms and workers adjust wages with some positive endogenously determined probability $\alpha_t^{j_w}$ in the j_w'th period following the last renegotiation (state dependent).
- Note that $\alpha_t^{J_w} = 1$ for some $J_w > 1$.

Bargaining

- When a firm/household pair renegotiates the wage, bargaining takes place in a setup similar to the model by Holden (1994).
- In the model, the parties bargain every period.
- Each bargaining round starts with one of the parties making a bid, then the other party responds yes or no.
- There are two key features of the Holden (1994) model.

Bargaining

- When a firm/household pair renegotiates the wage, bargaining takes place in a setup similar to the model by Holden (1994).
- In the model, the parties bargain every period.
- Each bargaining round starts with one of the parties making a bid, then the other party responds yes or no.
- There are two key features of the Holden (1994) model.

Bargaining

- When a firm/household pair renegotiates the wage, bargaining takes place in a setup similar to the model by Holden (1994).
- In the model, the parties bargain every period.
- Each bargaining round starts with one of the parties making a bid, then the other party responds yes or no.
- There are two key features of the Holden (1994) model.

Bargaining

- When a firm/household pair renegotiates the wage, bargaining takes place in a setup similar to the model by Holden (1994).
- In the model, the parties bargain every period.
- Each bargaining round starts with one of the parties making a bid, then the other party responds yes or no.
- There are two key features of the Holden (1994) model.

- First:
  - If the response is no, there is a choice whether to continue bargaining in good faith and post a counter offer or enter into disagreement.
  - If the latter choice is made, there is a probability that the match breaks down and the wage is determined in a standard Rubinstein-Ståhl fashion.
  - Moreover, in case a party initiate bargaining under disagreement, both parties face their own known fixed disagreement cost (randomly drawn at the beginning of each period). This cost may be due to deteriorating firm/worker relationships.
  - Similar to Holden (1994), but with probability of breakdown instead of strikes.

- First:
  - If the response is no, there is a choice whether to continue bargaining in good faith and post a counter offer or enter into disagreement.
  - If the latter choice is made, there is a probability that the match breaks down and the wage is determined in a standard Rubinstein-Ståhl fashion.
  - Moreover, in case a party initiate bargaining under disagreement, both parties face their own known fixed disagreement cost (randomly drawn at the beginning of each period). This cost may be due to deteriorating firm/worker relationships.
  - Similar to Holden (1994), but with probability of breakdown instead of strikes.

- First:
    - If the response is no, there is a choice whether to continue bargaining in good faith and post a counter offer or enter into disagreement.
    - If the latter choice is made, there is a probability that the match breaks down and the wage is determined in a standard Rubinstein-Ståhl fashion.
    - Moreover, in case a party initiate bargaining under disagreement, both parties face their own known fixed disagreement cost (randomly drawn at the beginning of each period). This cost may be due to deteriorating firm/worker relationships.
    - Similar to Holden (1994), but with probability of breakdown instead of strikes.

- First:
  - If the response is no, there is a choice whether to continue bargaining in good faith and post a counter offer or enter into disagreement.
  - If the latter choice is made, there is a probability that the match breaks down and the wage is determined in a standard Rubinstein-Ståhl fashion.
  - Moreover, in case a party initiate bargaining under disagreement, both parties face their own known fixed disagreement cost (randomly drawn at the beginning of each period). This cost may be due to deteriorating firm/worker relationships.
  - Similar to Holden (1994), but with probability of breakdown instead of strikes.

- First:
  - If the response is no, there is a choice whether to continue bargaining in good faith and post a counter offer or enter into disagreement.
  - If the latter choice is made, there is a probability that the match breaks down and the wage is determined in a standard Rubinstein-Ståhl fashion.
  - Moreover, in case a party initiate bargaining under disagreement, both parties face their own known fixed disagreement cost (randomly drawn at the beginning of each period). This cost may be due to deteriorating firm/worker relationships.
  - Similar to Holden (1994), but with probability of breakdown instead of strikes.

- Second:
  - There is an old contract in place at the firm and if there is no new wage agreement, workers work according to the old contract. As pointed out by Holden (1994), this is a common feature of many western European countries.
- As soon as there is bargaining under disagreement , payoffs are determined in a standard Rubinstein-Ståhl bargaining game and the disagreement costs is paid out of the parties respective pockets.
- A credible threat leads to immediate renegotiation and hence no disagreement in equilibrium.
- To derive only downward nominal rigidity, asymmetries in disagreement costs are required.
- Gives a standard formulation of the bargaining problem when there is disagreement, as in Christoffel, Kuester & Linzert (2009).

- Second:
    - There is an old contract in place at the firm and if there is no new wage agreement, workers work according to the old contract. As pointed out by Holden (1994), this is a common feature of many western European countries.
- As soon as there is bargaining under disagreement , payoffs are determined in a standard Rubinstein-Ståhl bargaining game and the disagreement costs is paid out of the parties respective pockets.
- A credible threat leads to immediate renegotiation and hence no disagreement in equilibrium.
- To derive only downward nominal rigidity, asymmetries in disagreement costs are required.
- Gives a standard formulation of the bargaining problem when there is disagreement, as in Christoffel et al. (2009).

- Second:
    - There is an old contract in place at the firm and if there is no new wage agreement, workers work according to the old contract. As pointed out by Holden (1994), this is a common feature of many western European countries.
- As soon as there is bargaining under disagreement , payoffs are determined in a standard Rubinstein-Ståhl bargaining game and the disagreement costs is paid out of the parties respective pockets.
- A credible threat leads to immediate renegotiation and hence no disagreement in equilibrium.
- To derive only downward nominal rigidity, asymmetries in disagreement costs are required.
- Gives a standard formulation of the bargaining problem when there is disagreement, as in Christoffel et al. (2009).

- Second:
    - There is an old contract in place at the firm and if there is no new wage agreement, workers work according to the old contract. As pointed out by Holden (1994), this is a common feature of many western European countries.
- As soon as there is bargaining under disagreement , payoffs are determined in a standard Rubinstein-Ståhl bargaining game and the disagreement costs is paid out of the parties respective pockets.
- A credible threat leads to immediate renegotiation and hence no disagreement in equilibrium.
- To derive only downward nominal rigidity, asymmetries in disagreement costs are required.
- Gives a standard formulation of the bargaining problem when there is disagreement, as in Christoffel et al. (2009).

- Second:
  - There is an old contract in place at the firm and if there is no new wage agreement, workers work according to the old contract. As pointed out by Holden (1994), this is a common feature of many western European countries.
- As soon as there is bargaining under disagreement , payoffs are determined in a standard Rubinstein-Ståhl bargaining game and the disagreement costs is paid out of the parties respective pockets.
- A credible threat leads to immediate renegotiation and hence no disagreement in equilibrium.
- To derive only downward nominal rigidity, asymmetries in disagreement costs are required.
- Gives a standard formulation of the bargaining problem when there is disagreement, as in Christoffel et al. (2009).

- Second:
  - There is an old contract in place at the firm and if there is no new wage agreement, workers work according to the old contract. As pointed out by Holden (1994), this is a common feature of many western European countries.
- As soon as there is bargaining under disagreement , payoffs are determined in a standard Rubinstein-Ståhl bargaining game and the disagreement costs is paid out of the parties respective pockets.
- A credible threat leads to immediate renegotiation and hence no disagreement in equilibrium.
- To derive only downward nominal rigidity, asymmetries in disagreement costs are required.
- Gives a standard formulation of the bargaining problem when there is disagreement, as in Christoffel et al. (2009).

- Value for the family of a worker at firm i is in period t is,

$$\begin{aligned} V_t^{jw}\left(w_t^{jw}, a_t\right) &= w_t^{jw} h_t\left(w_t^{jw}, a_t\right) - \kappa^L \frac{\left(h_t\left(w_t^{jw}, a_t\right)\right)^{1+\xi}}{1+\xi} \\ &+\beta \sum_{a_{t+1}\in A} E_t \Lambda_{t,t+1} \vartheta\left(a_{t+1}, a_t\right) \\ &\times \left[\rho \alpha_{t+1}^{jw+1}\left(w_{t+1}^{jw+1}, a_{t+1}\right) V_{t+1}^0\left(w_{t+1}^0, a_{t+1}\right)\right. \\ &+\rho\left(1-\alpha_{t+1}^{jw+1}\left(w_{t+1}^{jw+1}, a_{t+1}\right)\right) V_{t+1}^{jw+1}\left(w_{t+1}^{jw+1}, a_{t+1}\right) \\ &\left. + (1-\rho) U_{t+1}\right], \end{aligned} \tag{4}$$

where $\vartheta\left(a_{t+1}, a_t\right)$ denotes the transition probability from productivity state a_t to a_{t+1}.

- Since the firm has the right to manage, hours $h_t\left(w_t^{jw}, a_t\right)$ are determined by the firm by maximizing the per-period payoff in

$$p_t^w y_{it} - w_t^{jw} h_{it}.$$

- Value for the family of a worker at firm i is in period t is,

$$
\begin{aligned}
V_t^{jw}\left(w_t^{jw}, a_t\right) = \; & w_t^{jw} h_t\left(w_t^{jw}, a_t\right) - \kappa^L \frac{\left(h_t\left(w_t^{jw}, a_t\right)\right)^{1+\xi}}{1+\xi} \\
& + \beta \sum_{a_{t+1}\in A} E_t \Lambda_{t,t+1} \vartheta\left(a_{t+1}, a_t\right) \\
& \times \left[\rho \alpha_{t+1}^{jw+1}\left(w_{t+1}^{jw+1}, a_{t+1}\right) V_{t+1}^0\left(w_{t+1}^0, a_{t+1}\right)\right. \\
& + \rho\left(1-\alpha_{t+1}^{jw+1}\left(w_{t+1}^{jw+1}, a_{t+1}\right)\right) V_{t+1}^{jw+1}\left(w_{t+1}^{jw+1}, a_{t+1}\right) \\
& \left. + (1-\rho) U_{t+1}\right],
\end{aligned} \tag{4}
$$

where $\vartheta\left(a_{t+1}, a_t\right)$ denotes the transition probability from productivity state a_t to a_{t+1}.

- Since the firm has the right to manage, hours $h_t\left(w_t^{jw}, a_t\right)$ are determined by the firm by maximizing the per-period payoff in

$$p_t^w y_{it} - w_t^{jw} h_{it}.$$

- The value when being unemployed is

$$U_t = b_r + \beta E_t \Lambda_{t,t+1} \left(s_{t+1} V_{x,t+1} + (1 - s_{t+1}) U_{t+1} \right),$$

where s_t is the hiring rate and where

$$V_{x,t} = \sum_{j_w=0}^{J_w-1} \sum_{a_t \in A} \omega_t^{j_w} \left(w_{t+1}^{j_w+1}, a_t \right) V_t^{j_w} \left(w_t^{j_w}, a_t \right), \tag{5}$$

where $\omega_t^{j_w} \left(w_{t+1}^{j_w+1}, a_t \right)$ denotes the share of workers with wage $w_t^{j_w}$ and productivity a_t or, if new hires have flexible wages

$$V_{x,t} = \sum_{a_t \in A} \omega_t^{0} \left(w_{t+1}^{1}, a_t \right) V_t^{0} \left(w_t^{0}, a_t \right), \tag{6}$$

- The bargaining surplus is (similar to Christoffel et al. (2009))

$$H_t^{j_w} \left(w_t^{j_w}, a_t \right) = V_t^{j_w} \left(w_t^{j_w}, a_t \right) - U_t, \tag{7}$$

- The value when being unemployed is

$$U_t = b_r + \beta E_t \Lambda_{t,t+1} \left(s_{t+1} V_{x,t+1} + (1 - s_{t+1}) U_{t+1} \right),$$

where s_t is the hiring rate and where

$$V_{x,t} = \sum_{j_w=0}^{J_w-1} \sum_{a_t \in A} \omega_t^{j_w} \left(w_{t+1}^{j_w+1}, a_t \right) V_t^{j_w} \left(w_t^{j_w}, a_t \right), \tag{5}$$

where $\omega_t^{j_w} \left(w_{t+1}^{j_w+1}, a_t \right)$ denotes the share of workers with wage $w_t^{j_w}$ and productivity a_t or, if new hires have flexible wages

$$V_{x,t} = \sum_{a_t \in A} \omega_t^0 \left(w_{t+1}^1, a_t \right) V_t^0 \left(w_t^0, a_t \right), \tag{6}$$

- The bargaining surplus is (similar to Christoffel et al. (2009))

$$H_t^{j_w} \left(w_t^{j_w}, a_t \right) = V_t^{j_w} \left(w_t^{j_w}, a_t \right) - U_t, \tag{7}$$

- The value for the firm is

$$
\begin{aligned}
J_t^{j_w}\left(w_t^{j_w},a_t\right) &= p_t^w\left(a_t h_t\left(w_t^{j_w},a_t\right)\right)^{1-\gamma} - w_t^{j_w} h_t\left(w_t^{j_w},a_t\right) - \Phi \\
&+\beta \sum_{a_{t+1}\in A} \Lambda_{t,t+1}\vartheta\left(a_{t+1},a_t\right) \\
&\times\left[\alpha_{t+1}^{j_w+1}\left(w_{t+1}^{j_w+1},a_{t+1}\right)\left(\rho J_{t+1}^0\left(w_{t+1}^0,a_{t+1}\right)\right)\right. \qquad (8) \\
&\left.\left(1-\alpha_{t+1}^{j_w+1}\left(w_{t+1}^{j_w+1},a_{t+1}\right)\right)\rho J_{t+1}^{j_w+1}\left(w_{t+1}^{j_w+1},a_{t+1}\right)\right],
\end{aligned}
$$

where Φ are fixed consisting of a fixed labor cost Φ_L and a fixed capital cost Φ_K as in Christoffel et al. (2009).

- In case there is bargaining under disagreement, wages are determined according to

$$\max_{W_{it}^0} \left(H_t^0\left(w_t^0, a_t\right)\right)^{\varphi}\left(J_t^0\left(w_t^0, a_t\right)\right)^{1-\varphi}, \tag{9}$$

where $w_t^0 = \frac{W_t^0}{P_t}$ and φ denotes the bargaining power of workers.

- A firm that last renegotiated wages j periods ago can credibly call for bargaining under disagreement if the gain from adjusting the wage is larger that the disagreement cost.
- Similarly, the worker calls for bargaining under disagreement if the gain from adjusting is larger than the disagreement cost.

- In case there is bargaining under disagreement, wages are determined according to

$$\max_{W_{it}^0} \left(H_t^0 \left(w_t^0, a_t \right) \right)^{\varphi} \left(J_t^0 \left(w_t^0, a_t \right) \right)^{1-\varphi}, \tag{9}$$

where $w_t^0 = \frac{W_t^0}{P_t}$ and φ denotes the bargaining power of workers.
- A firm that last renegotiated wages j periods ago can credibly call for bargaining under disagreement if the gain from adjusting the wage is larger that the disagreement cost.
- Similarly, the worker calls for bargaining under disagreement if the gain from adjusting is larger than the disagreement cost.

- In case there is bargaining under disagreement, wages are determined according to

$$\max_{W_{it}^0} \left(H_t^0 \left(w_t^0, a_t \right) \right)^{\varphi} \left(J_t^0 \left(w_t^0, a_t \right) \right)^{1-\varphi}, \tag{9}$$

  where $w_t^0 = \frac{W_t^0}{P_t}$ and φ denotes the bargaining power of workers.
- A firm that last renegotiated wages j periods ago can credibly call for bargaining under disagreement if the gain from adjusting the wage is larger that the disagreement cost.
- Similarly, the worker calls for bargaining under disagreement if the gain from adjusting is larger than the disagreement cost.

Hiring and other constraints

- Entrant firms chooses vacancies so that the vacancy cost is equal to the expected value of filling a vacancy. Thus, determined by

$$\kappa_t v_t = m_t^a \beta \sum_{j_w=0}^{J_w-1} \sum_{a_{t+1} \in A} E_t \omega_t^{j_w} \left(w_{t+1}^{j_w+1}, a_{t+1} \right) \Lambda_{t,t+1} J_{t+1}^{j_w} \left(w_{t+1}^{j_w}, a_{t+1} \right). \tag{10}$$

- Flow equation of prices

$$p_t^j = \frac{p_{t-1}^{j-1}}{1+\pi_t},$$

and wages.

Hiring and other constraints

- Entrant firms chooses vacancies so that the vacancy cost is equal to the expected value of filling a vacancy. Thus, determined by

$$\kappa_t v_t = m_t^a \beta \sum_{j_w=0}^{J_w-1} \sum_{a_{t+1}\in A} E_t \omega_t^{j_w} \left(w_{t+1}^{j_w+1}, a_{t+1} \right) \Lambda_{t,t+1} J_{t+1}^{j_w} \left(w_{t+1}^{j_w}, a_{t+1} \right). \tag{10}$$

- Flow equation of prices

$$p_t^j = \frac{p_{t-1}^{j-1}}{1+\pi_t},$$

and wages.

Optimal policy - the Ramsey Problem

- We solve for the Ramsey optimal policy. The policymaker maximizes

$$E_t \sum_{r=t}^{\infty} \beta^{r-t} \left[u\left(c_r\right) - \int_i \kappa^L \frac{\left(h_{ir}\right)^{1+\xi}}{1+\xi} di \right]$$

subject to the constraints from the competitive equilibrium described above.

Calibration

- $u(c_t) = \log c_t$ and

Deep Parameters 1	
β	0.9928
σ	10
ξ	2
γ	1/3
prod gr	1.004
κ	0.085
Φ_K	1/3
Φ_L	0.0069

and

Deep Parameters 2	
b_r	0.48
ρ	0.9
σ_a	0.6
σ_m	0.83
A	0.0111
B	0.07524
φ	0.5
κ^L	24.3

- Productivity growth is 1.004 on a quarterly basis.
- To model the idiosyncratic productivity process, we use a four-state Markov chain with a quarterly persistence of 0.6 (bounded from above due to numerical reasons) and with a ratio between the max and the min state of $\frac{3.8750}{5.1250} \approx 0.76$.
- Replacement rate (the ratio of home production value to the average wage) of around 0.62.
- Hiring cost is around 0.14% of steady state output.

- Productivity growth is 1.004 on a quarterly basis.
- To model the idiosyncratic productivity process, we use a four-state Markov chain with a quarterly persistence of 0.6 (bounded from above due to numerical reasons) and with a ratio between the max and the min state of $\frac{3.8750}{5.1250} \approx 0.76$.
- Replacement rate (the ratio of home production value to the average wage) of around 0.62.
- Hiring cost is around 0.14% of steady state output.

- Productivity growth is 1.004 on a quarterly basis.
- To model the idiosyncratic productivity process, we use a four-state Markov chain with a quarterly persistence of 0.6 (bounded from above due to numerical reasons) and with a ratio between the max and the min state of $\frac{3.8750}{5.1250} \approx 0.76$.
- Replacement rate (the ratio of home production value to the average wage) of around 0.62.
- Hiring cost is around 0.14% of steady state output.

- Productivity growth is 1.004 on a quarterly basis.
- To model the idiosyncratic productivity process, we use a four-state Markov chain with a quarterly persistence of 0.6 (bounded from above due to numerical reasons) and with a ratio between the max and the min state of $\frac{3.8750}{5.1250} \approx 0.76$.
- Replacement rate (the ratio of home production value to the average wage) of around 0.62.
- Hiring cost is around 0.14% of steady state output.

- Bargaining power set to $\varphi = 0.5$.
- Intermediate goods producing firms price adjustment costs follows a beta distribution with parameters $l = 2.1$, $r = 1$ and upper bound 0.015.
- Disagreement costs in the wholesale sector also follows the beta distribution with parameters $l_H = 2.1$, $r_H = 1$ and $l_J = 2.1$, $r_J = 1$ and upper bounds $\mathcal{B}^H$ for workers and $\mathcal{B}^J$ for firms.
- To find the bounds $\mathcal{B}^H$ and $\mathcal{B}^J$, we fit the dispersion of yearly wage changes in the model (given a yearly inflation rate of 2 %) to the empirical dispersion of yearly wage changes in the US during the period 1993-1997 using a minimum distance estimator.

- Bargaining power set to $\varphi = 0.5$.
- Intermediate goods producing firms price adjustment costs follows a beta distribution with parameters $l = 2.1$, $r = 1$ and upper bound 0.015.
- Disagreement costs in the wholesale sector also follows the beta distribution with parameters $l_H = 2.1$, $r_H = 1$ and $l_J = 2.1$, $r_J = 1$ and upper bounds $\mathcal{B}^H$ for workers and $\mathcal{B}^J$ for firms.
- To find the bounds $\mathcal{B}^H$ and $\mathcal{B}^J$, we fit the dispersion of yearly wage changes in the model (given a yearly inflation rate of 2 %) to the empirical dispersion of yearly wage changes in the US during the period 1993-1997 using a minimum distance estimator.

- Bargaining power set to $\varphi = 0.5$.
- Intermediate goods producing firms price adjustment costs follows a beta distribution with parameters $l = 2.1$, $r = 1$ and upper bound 0.015.
- Disagreement costs in the wholesale sector also follows the beta distribution with parameters $l_H = 2.1$, $r_H = 1$ and $l_J = 2.1$, $r_J = 1$ and upper bounds $\mathcal{B}^H$ for workers and $\mathcal{B}^J$ for firms.
- To find the bounds $\mathcal{B}^H$ and $\mathcal{B}^J$, we fit the dispersion of yearly wage changes in the model (given a yearly inflation rate of 2 %) to the empirical dispersion of yearly wage changes in the US during the period 1993-1997 using a minimum distance estimator.

- Bargaining power set to $\varphi = 0.5$.
- Intermediate goods producing firms price adjustment costs follows a beta distribution with parameters $l = 2.1$, $r = 1$ and upper bound 0.015.
- Disagreement costs in the wholesale sector also follows the beta distribution with parameters $l_H = 2.1$, $r_H = 1$ and $l_J = 2.1$, $r_J = 1$ and upper bounds $\mathcal{B}^H$ for workers and $\mathcal{B}^J$ for firms.
- To find the bounds $\mathcal{B}^H$ and $\mathcal{B}^J$, we fit the dispersion of yearly wage changes in the model (given a yearly inflation rate of 2 %) to the empirical dispersion of yearly wage changes in the US during the period 1993-1997 using a minimum distance estimator.

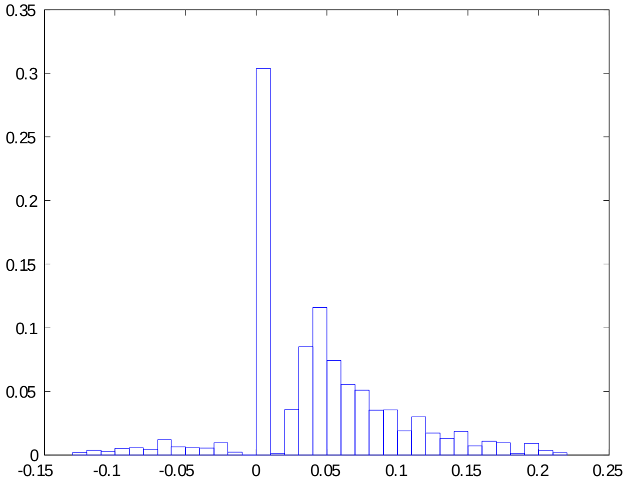


Figure: Empirical distribution of yearly nominal wage changes for stayers in the US during the period 1993-1997 (PSID, cleaned from measurement error)

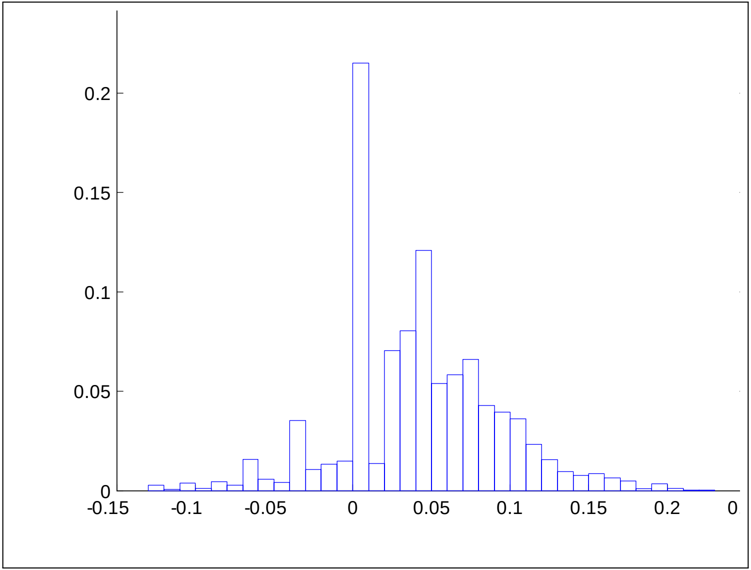


Figure: The yearly nominal wage change distribution implied by the model.

- This procedure yields parameters $\mathcal{B}^H = 0.0168$ for workers and for firms $\mathcal{B}^J = 0.2213$. When imposing a symmetry restriction, we find the upper bounds to equal $\mathcal{B}^H = \mathcal{B}^J = 0.0519$.

Results

- Baseline: Inflation around 1.2 %.

Table: Yearly optimal inflation rate under the Ramsey policy

	Asymmetric wage frictions	Symmetric wage frictions	Flexible wages
Baseline	1.21	0.36	−0.96
Flex wages for new hires	0.00		−0.96

Conclusions

- Inflation around 1.2 percent a year.
- Decomposition :
  - Flexible wages gives deflation of 0.96 percent.
  - Symmetric adjustment costs gives inflation of 0.36 percent.
  - Asymmetric adjustment costs gives inflation of 1.2 percent.

Conclusions

- Inflation around 1.2 percent a year.
- Decomposition :
    - Flexible wages gives deflation of 0.96 percent.
    - Symmetric adjustment costs gives inflation of 0.36 percent.
    - Asymmetric adjustment costs gives inflation of 1.2 percent.

Conclusions

- Inflation around 1.2 percent a year.
- Decomposition :
  - Flexible wages gives deflation of 0.96 percent.
  - Symmetric adjustment costs gives inflation of 0.36 percent.
  - Asymmetric adjustment costs gives inflation of 1.2 percent.

Conclusions

- Inflation around 1.2 percent a year.
- Decomposition :
    - Flexible wages gives deflation of 0.96 percent.
    - Symmetric adjustment costs gives inflation of 0.36 percent.
    - Asymmetric adjustment costs gives inflation of 1.2 percent.

Conclusions

- Inflation around 1.2 percent a year.
- Decomposition :
  - Flexible wages gives deflation of 0.96 percent.
  - Symmetric adjustment costs gives inflation of 0.36 percent.
  - Asymmetric adjustment costs gives inflation of 1.2 percent.

Extensions

- One distortion at a time.
- Hosios condition.
- Aggregate uncertainty/Dynamics - first and second order. Then the ZLB/liquidity trap becomes interesting as well.

Extensions

- One distortion at a time.
- Hosios condition.
- Aggregate uncertainty/Dynamics - first and second order. Then the ZLB/liquidity trap becomes interesting as well.

Extensions

- One distortion at a time.
- Hosios condition.
- Aggregate uncertainty/Dynamics - first and second order. Then the ZLB/liquidity trap becomes interesting as well.

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market:
- Inflation redistributes between workers and firm:
- Consider some π and average real wage in economy

Intuition

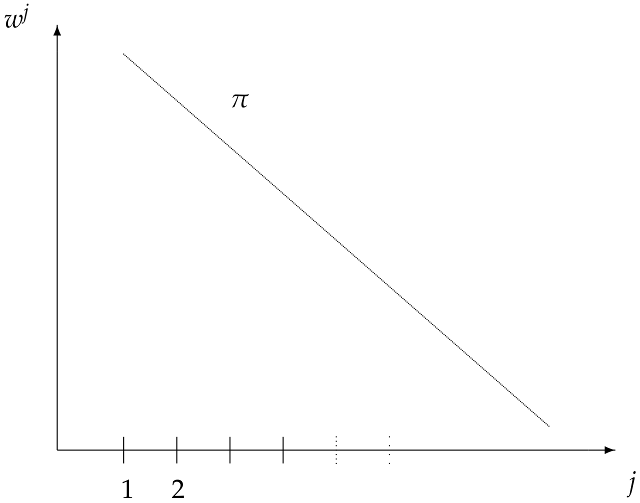
- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market:
- Inflation redistributes between workers and firm:
- Consider some π and average real wage in economy

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market:
- Inflation redistributes between workers and firm:
- Consider some π and average real wage in economy

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market:
- Inflation redistributes between workers and firm:
- Consider some π and average real wage in economy


w^j
π
1
2
j

Intuition

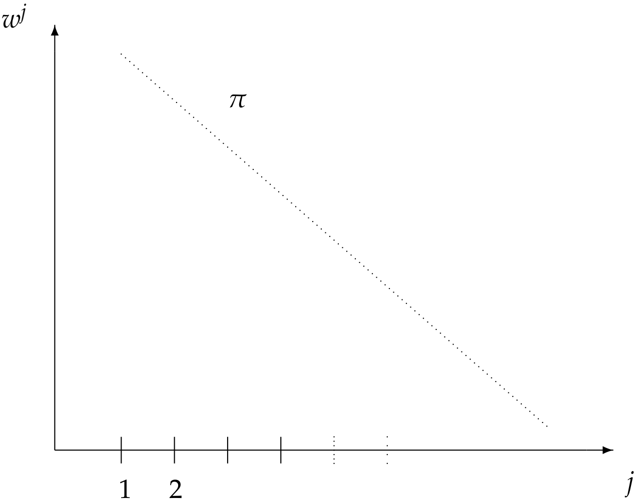
- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market
- Inflation redistributes between workers and firm

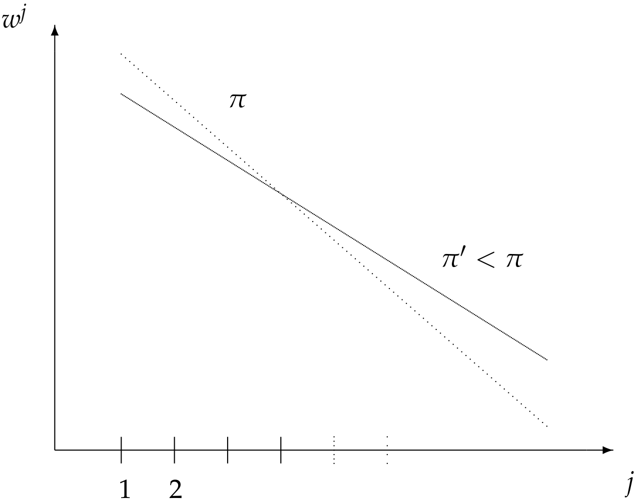
- Consider some π and average equilibrium real wage in economy
- Decrease π to π' and keep average real wage constant (NOT equilibrium)

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market
- Inflation redistributes between workers and firm

- Consider some π and average equilibrium real wage in economy
- Decrease π to π' and keep average real wage constant (NOT equilibrium)


w^j
π
1
2
j


w^j
π
$\pi' < \pi$
1
2
j

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market
- Inflation redistributes between workers and firm
- Consider some π and average equilibrium real wage in economy
- Decrease π to π' and keep average real wage constant (NOT equilibrium)
- Firm gains and worker looses because wage costs are a good for worker and a bad for firm
- Equilibrium average real wage goes up

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market
- Inflation redistributes between workers and firm
- Consider some π and average equilibrium real wage in economy
- Decrease π to π' and keep average real wage constant (NOT equilibrium)
- Firm gains and worker looses because wage costs are a good for worker and a bad for firm
- Equilibrium average real wage goes up

Intuition

- Real wages too high due to DNWR. - higher inflation erodes real wages at firms that have too high wages
- No DNWR: Still inefficient labor market
- Inflation redistributes between workers and firm
- Consider some π and average equilibrium real wage in economy
- Decrease π to π' and keep average real wage constant (NOT equilibrium)
- Firm gains and worker looses because wage costs are a good for worker and a bad for firm
- Equilibrium average real wage goes up

Additional - resource constraint

The resource constraint is

$$\int_0^1 y_{it} di + (1 - n_t) b_r = \sum_{j=0}^{J-1} \omega_j \left(p_t^j\right)^{-\varepsilon} \left(c_t \left(1 + s\left(\frac{c_t}{m_t}\right)\right)\right) + \frac{\kappa_t}{2} \int_0^1 x_{it}^2 n_{it-1} di + \sum_{j=0}^{J-1} \omega_j \Xi_{j,t}$$

Additional - consumer first-order conditions

$$
\begin{aligned}
u_c(c_t) &= \lambda_t \left(1 + s\left(\frac{c_t}{m_t}\right) + c_t s'\left(\frac{c_t}{m_t}\right)\frac{1}{m_t}\right) \\
E_t \beta \lambda_{t+1} &= \lambda_t \left(-\frac{c_t^2}{m_t^2} s'\left(\frac{c_t}{m_t}\right) + 1\right) \\
\frac{\lambda_t}{R_t} &= \beta E_t \frac{\lambda_{t+1}}{1+\pi_{t+1}}
\end{aligned}
$$

Additional - employment transition equations

Employment transition equations are

$$n_t^0 = \sum_{j=1}^{J_w} \left(\rho + x_t^0\right) \alpha_w^j n_{t-1}^{j-1}$$

and, for $j > 0$,

$$n_t^j = \left(\rho + x_t^j\right) \left(1 - \alpha_w^j\right) n_{t-1}^{j-1}$$

Additional - firm values

The value of the firm is

$$F\left(w_{it}\right) = p_t^w y_{it} - w_{it} n_{it} - \frac{\kappa_t}{2}\left(x_{it}\right)^2 n_{it-1} - r_t^k k_{it} + \beta E_t \Lambda_{t,t+1} F\left(w_{it+1}\right)$$

Let $J_t\left(w_{it}\right)$ be the value of a worker at the firm, given that the worker is at the firm,

$$J_t\left(w_{it}\right) = \frac{\partial\left(p_t^w y_{it} - w_t^j n_{it} - r_t^k k_{it} + \beta E_t \Lambda_{t,t+1} F\left(w_{it+1}\right)\right)}{\partial n_{it}}$$

The value of an additional employee is

$$\begin{aligned}
\frac{F_t\left(w_{it}\right)}{\partial n_{it-1}} &= -\frac{\kappa_t}{2}x_{it}^2 \\
&+ \left(\frac{\partial\left(p_t^w y_{it} - w_{it}n_{it} - r_t^k k_{it}\right)}{\partial n_{it}} + \beta E_t \Lambda_{t,t+1}\frac{\partial F\left(w_{it+1}\right)}{\partial n_{it}}\right)\left(\rho + x_{it}\right) \\
&= -\frac{\kappa_t}{2}x_{it}^2 + \left(\rho + x_{it}\right)J_t\left(w_{it}\right)
\end{aligned}$$

The effect on firm profits of an additional employee is

$$J_t\left(w_{it}\right) = p_t^w\left(1-\gamma\right)\frac{y_{it}}{n_{it}} - w_{it} + \beta E_t \Lambda_{t,t+1}\left(-\frac{\kappa_t}{2}x_{it+1}^2 + \left(\rho + x_{it+1}\right)J_t\left(w_{it+1}\right)\right)$$

Additional - adjustment probabilities

Let

$$\begin{aligned} dF_t^j &= J_t\left(w_t^0\right) - J_t\left(w_t^j\right) \\ dU_t^j &= H_t\left(w_t^0\right) - H_t\left(w_t^j\right) \end{aligned}$$

The fraction of firms that calls for bargaining under disagreement is

$$\begin{array}{cc} 1 & \text{if } \mathcal{B}^F < F_t^j \\ G^F\left(dF_t^j\right) & 0 \leq dF_t^j \leq \mathcal{B}^F \\ 0 & dF_t^j < 0 \end{array}$$

Similarly, the fraction of workers that has an incentive to call for bargaining under disagreement to force a renegotiation of the wage contract is

$$G^{U}\left(dU_t^j\right) \quad \begin{matrix} 1 & \text{if } \mathcal{B}^{U} < dU_t^j \\ & 0 \leq dU_t^j \leq \mathcal{B}^{U} \\ 0 & dU_t^j < 0 \end{matrix}$$

The adjustment probabilities are then

$$\alpha_t^j = \begin{cases} 1 & \text{if } \mathcal{B}^F < dF_t^j \text{ or if } \mathcal{B}^U < dU_t^j \\ G^F\left(dF_t^j\right) + G^U\left(dU_t^j\right) & 0 \le dF_t^j \le \mathcal{B}^F \\ -G^U\left(dU_t^j\right) G^F\left(dF_t^j\right) & \text{and } 0 \le dU_t^j \le \mathcal{B}^U \\ G^F\left(dF_t^j\right) & 0 \le dF_t^j \le \mathcal{B}^F \text{ and } dU_t^j < 0 \\ G^U\left(dU_t^j\right) & dF_t^j < 0 \text{ and } 0 \le dU_t^j \le \mathcal{B}^U \\ 0 & dF_t^j < 0 \text{ and } dU_t^j < 0 \end{cases}$$

Agell, J. & Lundborg, P. (2003), 'Survey evidence on wage rigidity and unemployment: Sweden in the 1990s', *Scandinavian Journal of Economics* **105**, 15–29.

Akerlof, G., Dickens, W. T. & Perry, G. (1996), 'The macroeconomics of low inflation', *Brookings Papers on Economic Activity* (1).

Altonji, J. & Devereux, P. (2000), The extent and consequences of downward nominal wage rigidity, *in* S. Polachek, ed., 'Research in Labor Economics', Vol. 19, Elsevier, pp. 383–431.

Baker, G., Gibbs, M. & Holmstrom, B. (1994), 'The wage policy of a firm', *Quarterly Journal of Economics* **109**, 921–955.

Bewley, T. (1999), *Why Wages Don't Fall During a Recession.*, Harvard University Press, Cambridge, MA.

Christoffel, K., Kuester, K. & Linzert, T. (2009), The role of labor markets for euro area monetary policy. FRBP Working Paper No. 09-01.

Dotsey, M., King, R. & Wolman, A. (1999), 'State-dependent pricing and the general equilibrium dynamics of money and output', *Quarterly Journal of Economics* **114**, 655–690.

Fagan, G. & Messina, J. (2009), Downward wage rigidity and optimal steady state inflation. ECB Working Paper 1048.

Fehr, E. & Goette, L. (2005), 'Robustness and real consequences of nominal wage rigidity', *Journal of Monetary Economics* **52**, 779–804.

Holden, S. (1994), 'Wage bargaining and nominal rigidities', *European Economic Review* **38**, 1021–1039.

Holden, S. & Wulfsberg, F. (2008), 'Downward nominal wage rigidity in the oecd', *The B.E. Journal of Macroeconomics* **8 : Iss. 1 (Advances), Article 15.**

Kim, J. & Ruge-Murcia, F. (2010), Monetary policy when wages are downwardly rigid: Friedman meets tobin. forthcoming *Journal of Economic Dynamics and Control*.

Lie, D. (2010), State-dependent pricing and optimal monetary policy. Federal Reserve Bank of Boston Working Paper 09-22.

Schmitt-Grohe, S. & Uribe, M. (2004), 'Optimal fiscal and monetary policy under sticky prices', *Journal of Economic Theory* **114**, 198–230.

Schmitt-Grohe, S. & Uribe, M. (2010), The optimal rate of inflation. Forthcoming in Handbook in Macroeconomics.

Tobin, J. (1972), 'Inflation and unemployment', *American Economic Review* **62**, 1–18.

Wilson, B. A. (1999), Wage rigidity: A look inside the firm. Mimeo, Federal Reserve Board of Governors.