Rationing Under Sticky Prices

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Slides available at https://www.tholden.org/. EXTREMELY PRELIMINARY!

Sticky prices lead to rationing

- If a firm cannot adjust its nominal price, then its real price will decline over time at the rate of inflation.
- A lower real price implies higher demand for its good. Higher demand means higher marginal costs.
- Eventually, its marginal costs (rising) will be greater than its price (falling) if it continues to meet all demand.
- But no firm wants to sell at a price below marginal cost. Instead, it will stop producing, rationing demand.
- Yet essentially all the prior sticky price literature (Calvo or menu cost) assumes that firms always meet all demand.
- This paper: What are the macroeconomic implications of allowing firms to ration? Phillips curve? Welfare?

Does rationing matter in practice?

"Mark-ups are 10%, inflation is 2%, prices are updated at least once per year, real prices will not hit marginal cost."

- But: firm demand: $y \propto (\frac{p}{P})^{-\epsilon}$ ($\epsilon \approx 10$) and marginal costs: $mc \propto y^{\frac{\alpha}{1-\alpha}}$ ($\alpha \approx \frac{1}{3}$), so $mc \propto (\frac{p}{P})^{-\epsilon \frac{\alpha}{1-\alpha}} \approx (\frac{p}{P})^{-5}$.

- So: A 2% fall in real prices increases marginal costs by 10%. Good-bye mark-ups! Hello rationing!

- Additionally:

  - Firms face high frequency demand fluctuations. Mark-ups are much lower at times of high demand.
  - Inflation can be much higher than 2%. It was near 10% post-Covid!
  - In the short run, some labour and intermediate inputs are fixed ($\approx \frac{1}{3}$ at annual freq. (Abraham et al. 2024)). This implies $\alpha \gg \frac{1}{3}$.
  - Marginal costs are also rising over time if not all capital depreciation can be fixed quickly.
  - Demand is also growing over time due to aggregate income growth. A 2% increase in aggregate demand increases MC by 1%.

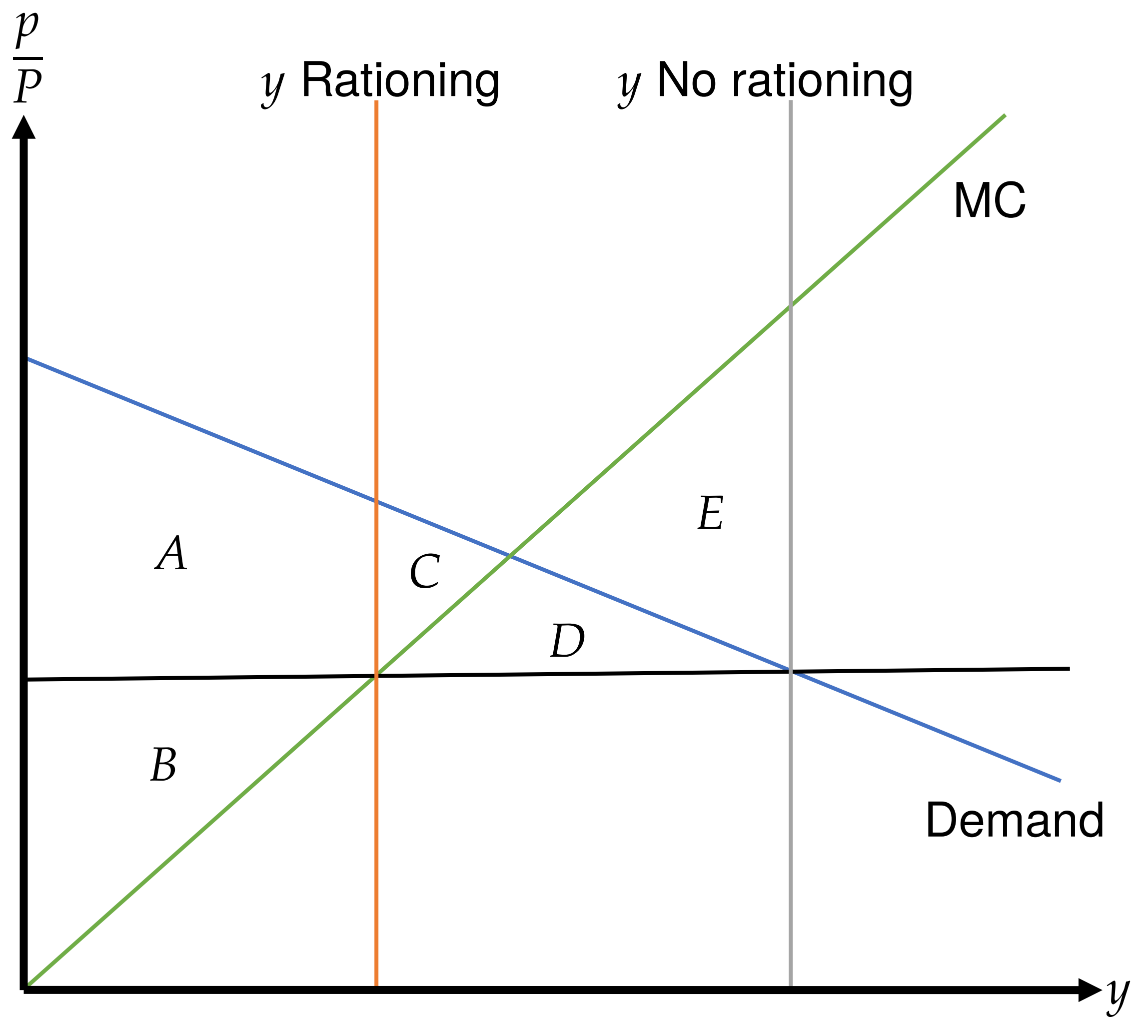
Empirical evidence for rationing

- Cavallo & Kryvtsov (2023) find that around 10% of all consumer goods were out of stock (=rationing) pre-pandemic.
- In the pandemic, this number went up to around 40%. In line with my story: high inflation $\Rightarrow$ high rationing.
  - Cavallo & Kryvtsov (2023) stress causality in the opposite direction. (Stockouts lead to inflation.)

- I'll show: Rationing helps match the immediate response of output to cleanly identified monetary policy shocks.
  - "Clean" monetary shock papers: Miranda-Agrippino & Ricco (2021), Bauer & Swanson (2023).
- I'll also show: Rationing helps match the estimated convexity of the Phillips curve (Forbes, Gagnon & Collins 2022).

- Almost all evidence supporting your favourite sticky price model will also support that model with rationing added.
  - This paper is not about a new model. It is about removing one approximation (no rationing) used in solving old models.
- Future versions of this paper may look more seriously at micro data.

The microeconomics of rationing vs excess production



- Without rationing: CS is $A + C + D$. PS is $B - D - E$.
- Without rationing: Welfare is $A + B + C - E$.
- With rationing: CS is A. PS is B. Welfare is $A + B$.
- Welfare is higher with rationing when $E > C$.
- Plausible as demand ($\propto y^{-\frac{1}{\epsilon}}$) is flatter than MC ($\propto y^{\frac{\alpha}{1-\alpha}}$).
- The economy with rationing should be less distorted!

The macroeconomics of rationing vs excess production

- If too much is produced by some firms (with old prices), other firms face higher marginal costs, so produce less.
- Demand is shifted from undistorted firms (with new prices) to distorted ones (with old prices).
- Bad!

- If demand is rationed for some goods (with old prices), other firms face lower marginal costs, so produce more.
- Demand is shifted from distorted firms (with old prices) to undistorted ones (with new prices).
- Good!

Prior literature

- Early papers:
    - Drèze (1975) Barro (1977), Svensson (1984).
    - Corsetti & Pesenti (2005): Restrict shocks to ensure no rationing.
- Papers looking at stockouts in inventory models:
    - Alessandria, Kaboski & Midrigan (2010), Kryvtsov & Midrigan (2013), Bils (2016).
    - In all these papers, firms always meet demand if they have stock available, even if value of that stock $>$ price.
- On rationing under sticky wages:
    - Huo & Ríos-Rull (2020), Gerke et al. (2023). Infinite dimensional state, primarily numerical results.
- Other related work:
    - Continuous time NK models: Posch, Rubio-Ramírez & Fernández-Villaverde (2011), (2018)
    - On endogenous price adjustment frequency: Blanco et al. (2024).

The model

Basics: Set-up, households, monetary policy

- The model is in continuous time, with no aggregate uncertainty, just MIT shocks.

- In period τ, households maximize: $\int_{\tau}^{\infty} e^{-\int_{\tau}^{t} \rho_{\upsilon}\, d_{\upsilon}} \left[\log Y_t - \Psi_t \frac{1}{1+\nu} L_t^{1+\nu}\right] dt$ where $\nu > 0$, $\Psi_t > 0$, $\rho_t > 0$.

- They face the budget constraint: $Y_t + \frac{\dot{B}_t^{(i)}}{P_t} + \dot{B}_t^{(r)} = W_t L_t + i_t \frac{B_t^{(i)}}{P_t} + r_t B_t^{(r)} + \mathrm{T}_t$.

    - $B_t^{(i)}$ nominal bonds. $B_t^{(r)}$ real bonds. Y_t output = consumption, at price P_t. W_t wage. L_t labour. T_t profits from owning firms.

- FOCs imply $\Psi_t L_t^{\nu} = \frac{W_t}{Y_t}$, $r_t = \rho_t + \frac{\dot{Y}_t}{Y_t}$, $i_t = r_t + \pi_t$, where $\pi_t = \frac{\dot{P}_t}{P_t}$.

- Monetary policy sets $i_t = r_t + \pi_t^* + \phi(\pi_t - \pi_t^*)$ with $\phi > 1$ and π_t^* an exogenous target (Holden 2024).

- From Fisher equation, $r_t + \pi_t = i_t = r_t + \pi_t^* + \phi(\pi_t - \pi_t^*)$, so $\pi_t = \pi_t^*$ for all t. Inflation is exogenous.

Aggregators

- We will assume firm price change opportunities arrive at rate $\xi_t > 0$.
- The time t density of firms that last updated at τ is $\xi_\tau e^{-\int_\tau^t \xi_\upsilon \, d\upsilon}$. Note $\int_{-\infty}^t \xi_\tau e^{-\int_\tau^t \xi_\upsilon \, d\upsilon} \, d\tau = 1$.
- We will index firms (and their products) by the time they last updated their price, and by their demand shock ζ.
- The aggregate good is produced from intermediates by a perfectly competitive industry with technology:

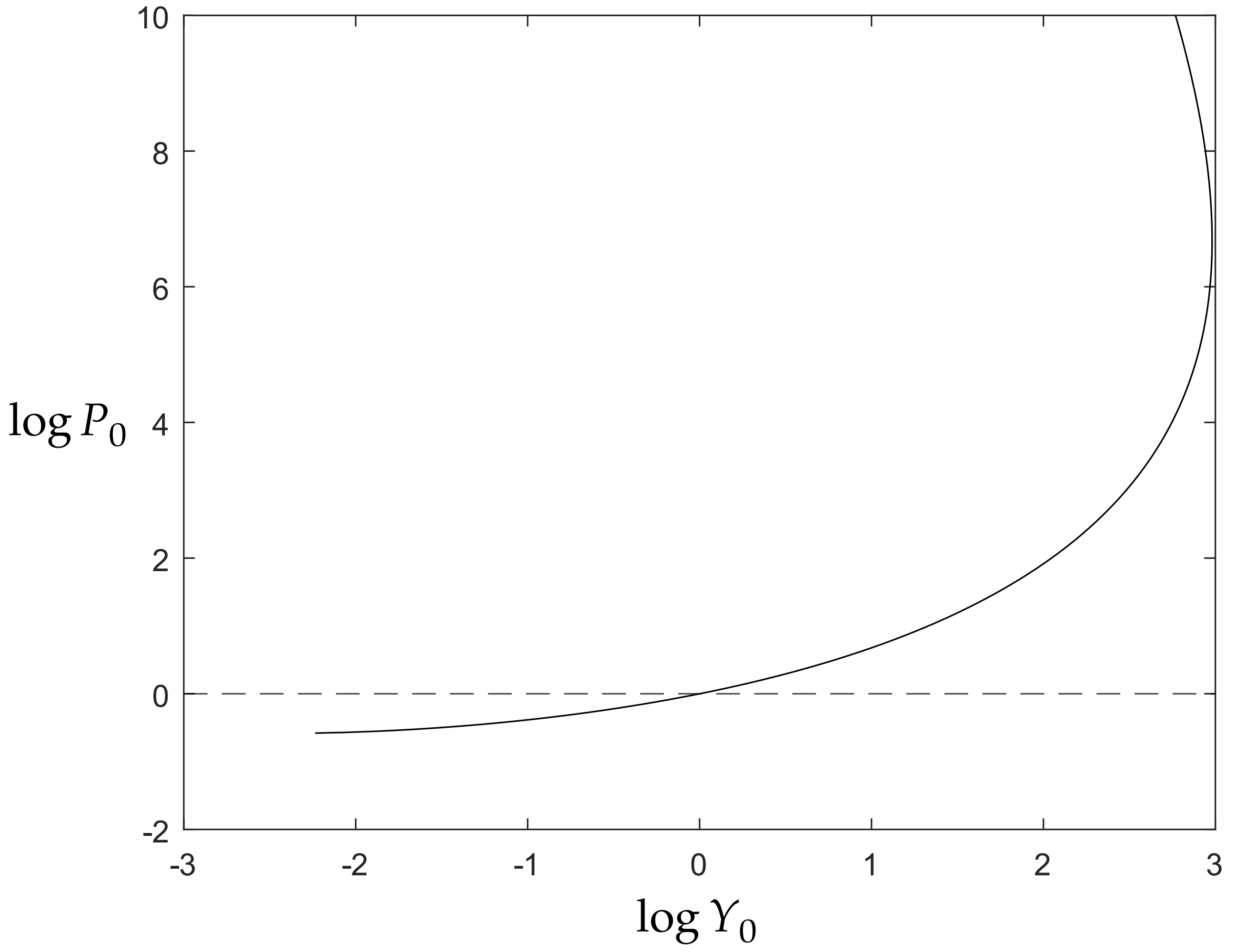
$$Y_t = \left[\int_{-\infty}^t \xi_\tau e^{-\int_\tau^t \xi_\upsilon \, d\upsilon} \int_0^1 \zeta y_{\zeta,\tau,t}^{\frac{\epsilon-1}{\epsilon}} g(\zeta) \, d\zeta \, d\tau\right]^{\frac{\epsilon}{\epsilon-1}} \left[\int_0^1 \zeta g(\zeta) \, d\zeta\right]^{-\frac{\epsilon}{\epsilon-1}}$$

- $g(\zeta)$ is the PDF of the demand shock, which is independent across time and firms.
- For tractability, we assume $g(\zeta) = \theta\zeta^{\theta-1}$ where $\theta > 0$ (so $\zeta \sim$ Beta$(\theta, 1)$). Mean ζ: $\frac{\theta}{\theta+1}$. Variance ζ: $\frac{\theta}{(\theta+1)^2(\theta+2)}$.
  - We will use an empirical moment not targeted by the prior literature to pin down θ.

Firm production (and rationing!) choices

- The FOC of the aggregators imply demand must satisfy: $y_{\zeta,\tau,t} \leq \left(\frac{\theta}{\theta+1}\frac{1}{\zeta}\frac{p_\tau}{P_t}\right)^{-\epsilon} Y_t$.
- Firms produce using the production technology: $y_{\zeta,\tau,t} = (A_t l_{\zeta,\tau,t})^{1-\alpha}$. Real wage is W_t. Define $\widehat{W}_t := \frac{W_t}{A_t}$.
- Firm flow real production profits: $o_{\zeta,\tau,t} = \frac{p_\tau}{P_t}(A_t l_{\zeta,\tau,t})^{1-\alpha} - W_t l_{\zeta,\tau,t}$. Guaranteed to be positive for small enough $l_{\zeta,\tau,t}$.
- Optimal production: There is a quantity $\bar{\zeta}_{\tau,t} := \frac{\theta}{\theta+1}\left(\frac{p_\tau}{P_t}\right)^{1+\frac{1-\alpha}{\epsilon\alpha}} \left(\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{1-\alpha}{\epsilon\alpha}} Y_t^{-\frac{1}{\epsilon}} > 0$ such that:
- If $\zeta < \bar{\zeta}_{\tau,t}$, there is no rationing, so: $y_{\zeta,\tau,t} = \left(\frac{\theta}{\theta+1}\frac{1}{\zeta}\frac{p_\tau}{P_t}\right)^{-\epsilon} Y_t$ and $A_t l_{\zeta,\tau,t} = \left[\left(\frac{\theta}{\theta+1}\frac{1}{\zeta}\frac{p_\tau}{P_t}\right)^{-\epsilon} Y_t\right]^{\frac{1}{1-\alpha}}$.
- If $\zeta > \bar{\zeta}_{\tau,t}$, there is rationing, so: $y_{\zeta,\tau,t} = \left(\frac{p_\tau}{P_t}\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{1-\alpha}{\alpha}}$ and $A_t l_{\zeta,\tau,t} = \left(\frac{p_\tau}{P_t}\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{1}{\alpha}}$.

The short-run Phillips curve



- Assume: $P_t = \exp(\pi t)$ for $t < 0$.
- And: $P_t = P_0 \exp(\pi t)$ for $t \geq 0$.
- So, prices jump at time 0.
- Graphs plot possible (Y_0, P_0).

- Solid line is short-run PC allowing rationing.
- Dashed line is short-run PC without rationing.

- Independent of price setting!

- Full calibration will be given shortly.

The short-run Phillips curve in the data

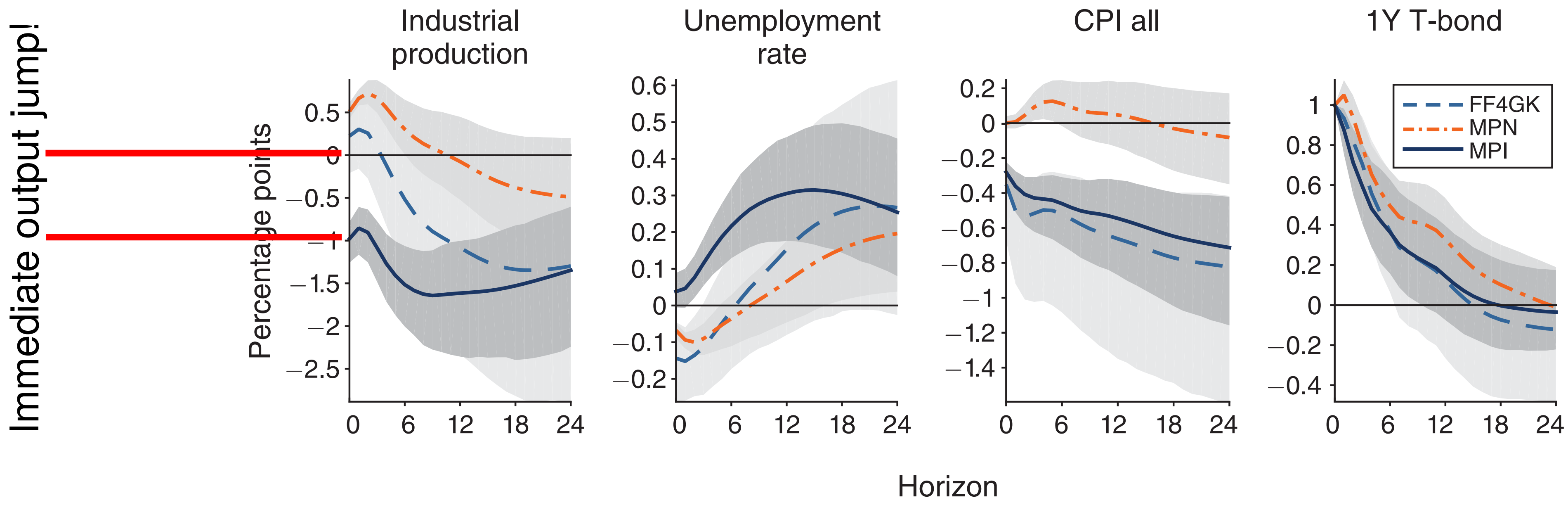


FIGURE 3. RESPONSES TO MONETARY POLICY SHOCK UNDER DIFFERENT IDENTIFICATIONS

Notes: Six-variable VAR. Shock identified with Gertler and Karadi's (2015) average monthly market surprise (teal, dashed), extended narrative measure of Romer and Romer (2004) (orange, dash-dotted), and informationally robust MPI_t series (dark blue lines). The shock is normalized to induce a 100 basis point increase in the 1-year rate. Sample 1979:1–2014:12. Shaded areas are 90 percent posterior coverage bands.

From Miranda-Agrippino & Ricco (2021).

Mapping IP to Brave-Butters-Kelley GDP (via relative SDs) this corresponds to a PC slope of 0.508.

Price change opportunity arrival rate choice

- If long-run inflation is higher, then plausibly prices would be changed more frequently.
  - At least aggregate state dependence is necessary for reasonable comparative static results.
  - I broadly follow Blanco et al. (2024) in modelling an endogenous rate of price change opportunities.

- Suppose all firms are owned by conglomerates. Each conglomerate owns countably many firms.
- Each conglomerate chooses the price adjustment rate ξ_t for the firms it owns (the same rate for all firms).
  - The conglomerate maximizes its firms' total profit, minus a cost of $\frac{1}{2}\kappa\xi_t^2$ labour units. New labour FOC $\Psi_t(L_t+\frac{1}{2}\kappa\xi_t^2)^\nu=\frac{A_t\widehat{W}_t}{Y_t}$.
- The conglomerate cannot control which particular firms update at any point in time, only the total quantity.
  - Surprisingly consistent with price micro data, which finds hazard rates are flat in price age (Klenow & Malin 2010).
- Optimal: $\xi_t=\frac{1}{\kappa}\frac{o_t-Q_t^*}{W_t}$, where $o_\tau:=\int_\tau^\infty e^{-\int_\tau^t \xi_\upsilon\,d\upsilon-\int_\tau^t r_\upsilon\,d_\upsilon} o_{\tau,t}\,dt$, $Q_s^*:=\int_{-\infty}^s \xi_\tau e^{-\int_\tau^s \xi_\upsilon\,d\upsilon}\int_s^\infty e^{-\int_s^t \xi_\upsilon\,d\upsilon-\int_s^t r_\upsilon\,d_\upsilon} o_{\tau,t}\,dt\,d\tau$.

Parameterization / Calibration

- $\alpha := \frac{1}{3}$, $\rho = 2\%$. $\pi = \pi^* = 2\%$ unless otherwise stated. Standard(ish).
- $\epsilon := 10$, $\xi := -4\log(0.65)$, $\nu := 2$. Smets & Wouters (2007).
- $\theta = 14.2$. Matching local short-run Phillips curve slope of 0.508 derived from Miranda-Agrippino & Ricco (2021).
- With an endogenous ξ_t, κ is chosen to match the steady-state level of ξ above when $\pi = 2\%$.
  - With rationing allowed, 0.2% of all labour is used for price adjustment. Without rationing, this number is 0.8%.
  - Rationing reduces the price adjustment frictions needed to match the data!
- $A := 1$. $\Psi := 1$ when ξ_t is exogenous. Units.
  - When ξ_t is endogenous, Ψ is chosen to match production labour between the endogenous & exogenous models when $\pi = 2\%$.

Results

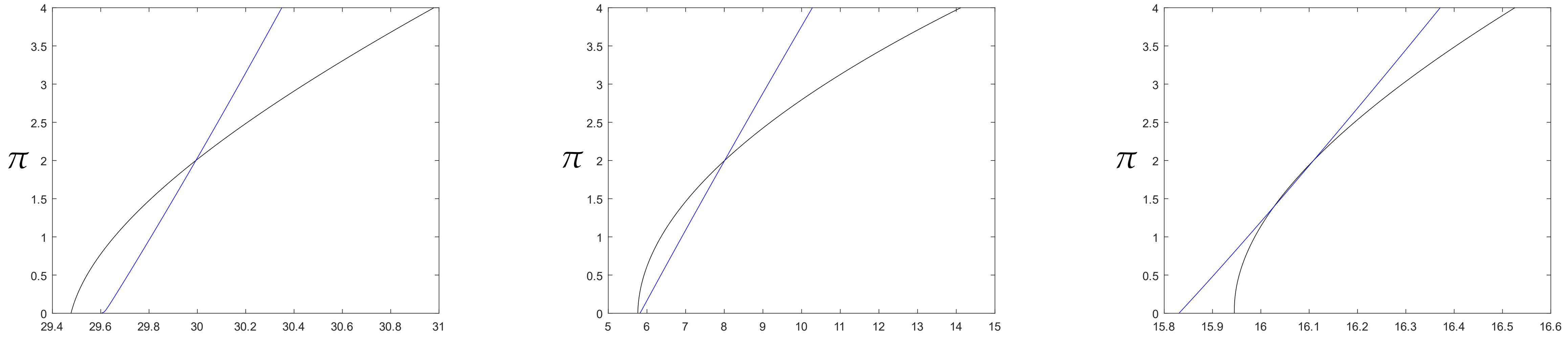
Comparative statics results

- How does the economy change as the long-run inflation rate is varied?

- In most of the following plots:
  - Black solid lines are the model with rationing, without endogenous ξ_t.
  - Black dashed lines are the model without rationing, without endogenous ξ_t.
  - Blue solid lines are the model with rationing, with endogenous ξ_t.
  - Blue dashed lines are the model without rationing, with endogenous ξ_t.

- Unless otherwise stated, units are percent or percentage points.

Rationing as a function of inflation



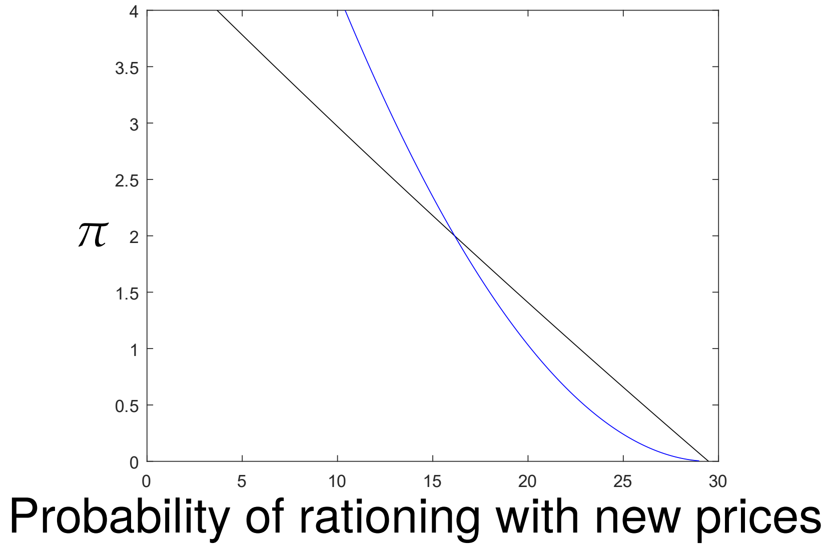
Average probability of rationing

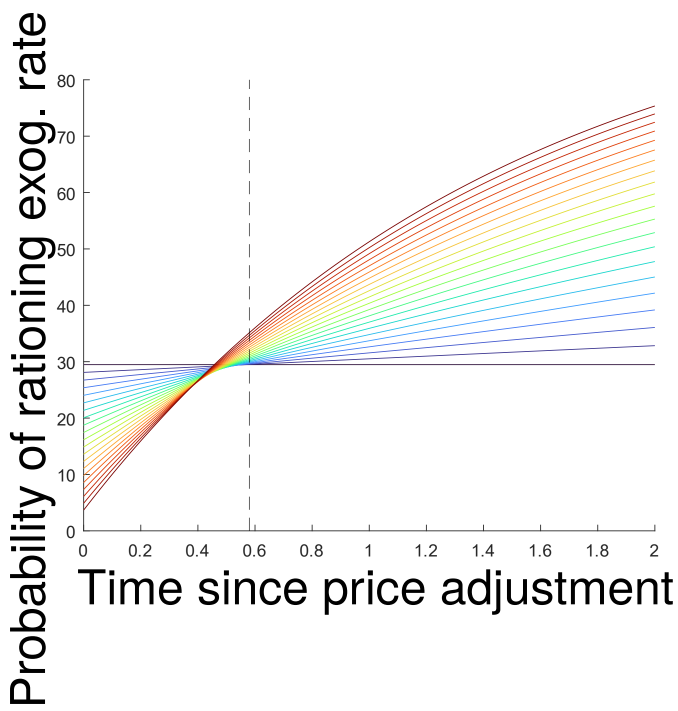
Excess demand

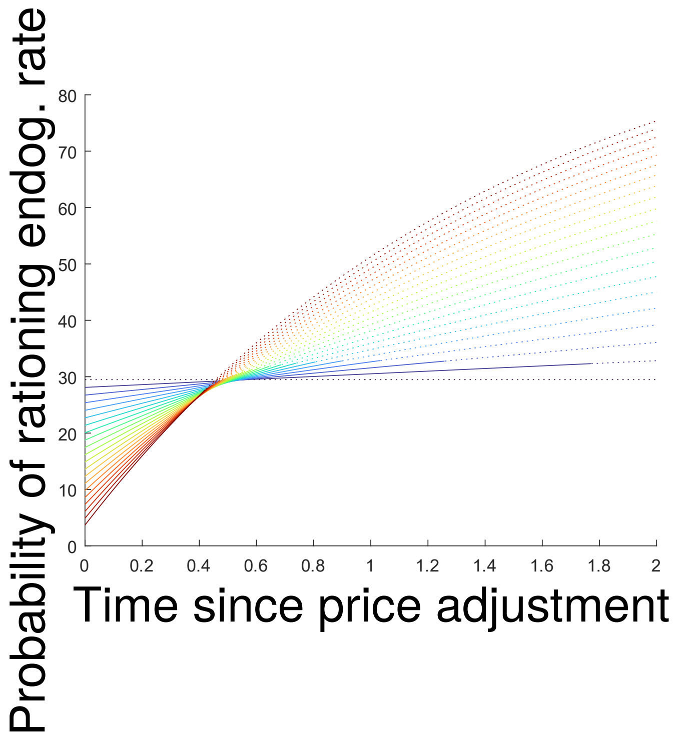
Aggregator profit share of output

When inflation is high rationing (and related quantities) are high. High inflation quickly erodes mark-ups.

Which firms ration?



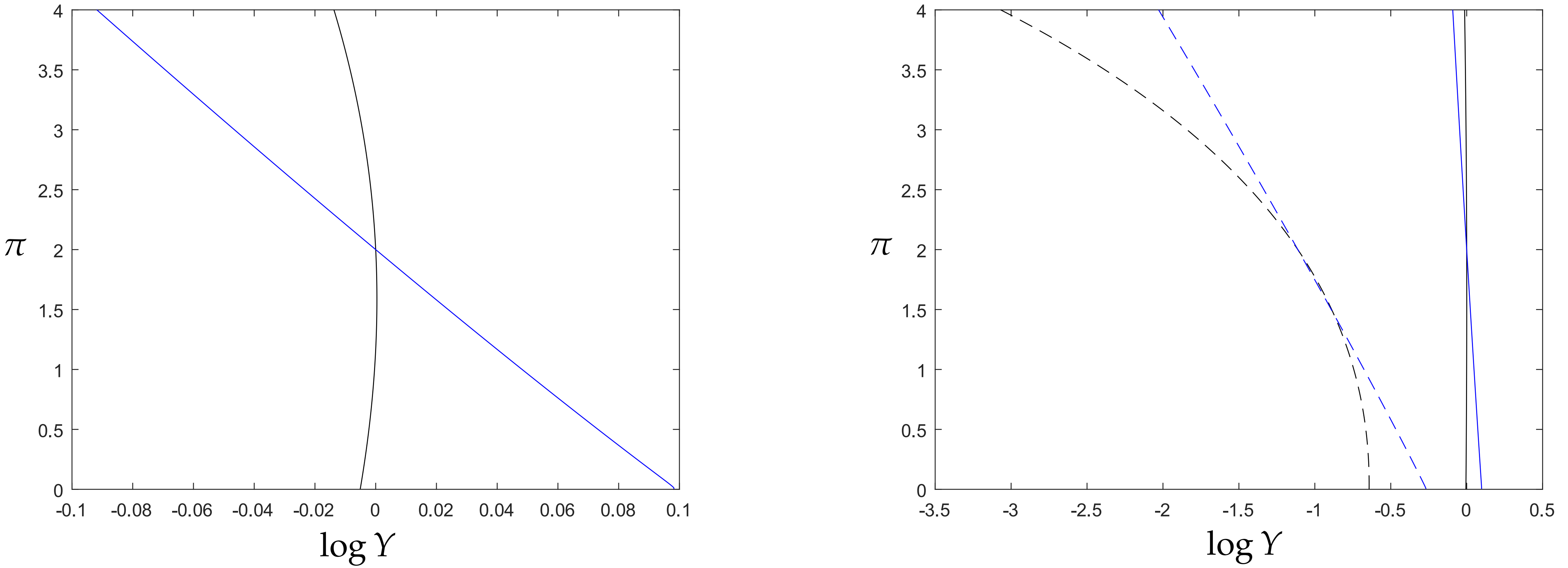




When inflation is high, firms with new prices set high mark-ups, giving them a low probability of rationing.

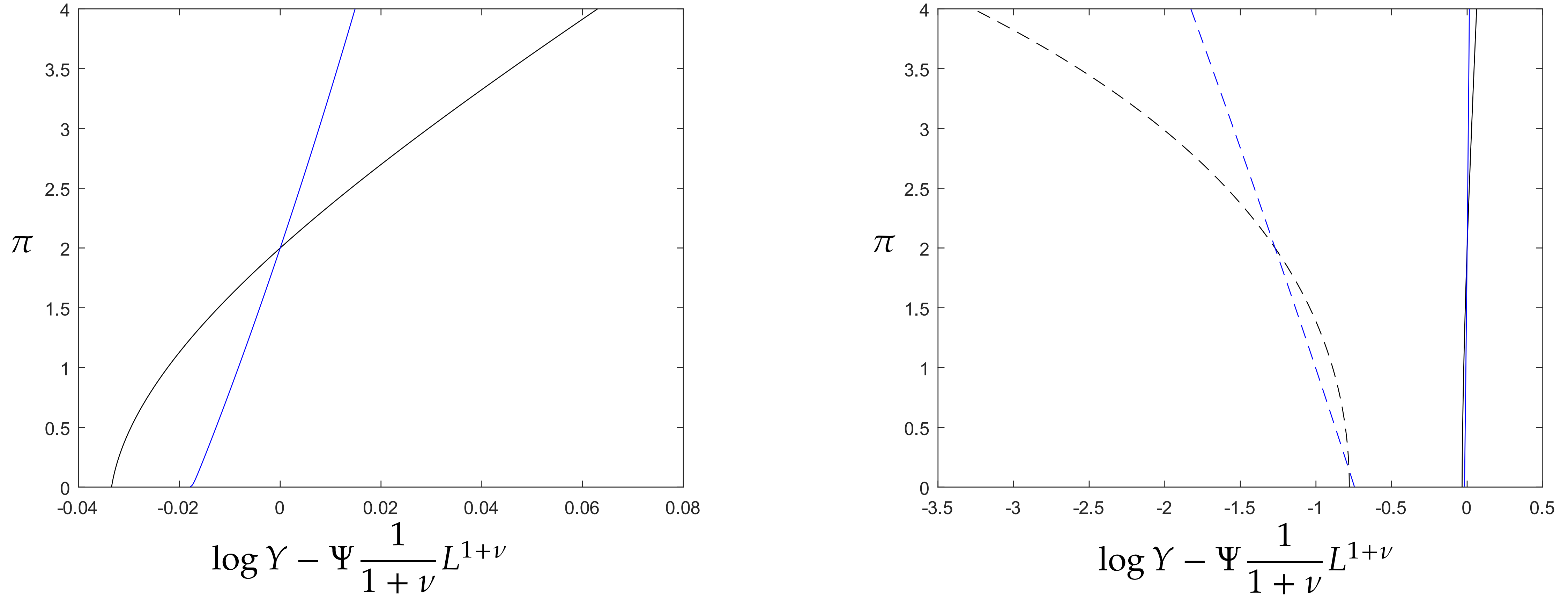
But as mark-ups are eroded by inflation, the probability of rationing increases. The old firms dominate.

The long-run Phillips curve



Output costs of inflation are much lower under rationing. 2% is about optimal for output with rationing and fixed ξ.

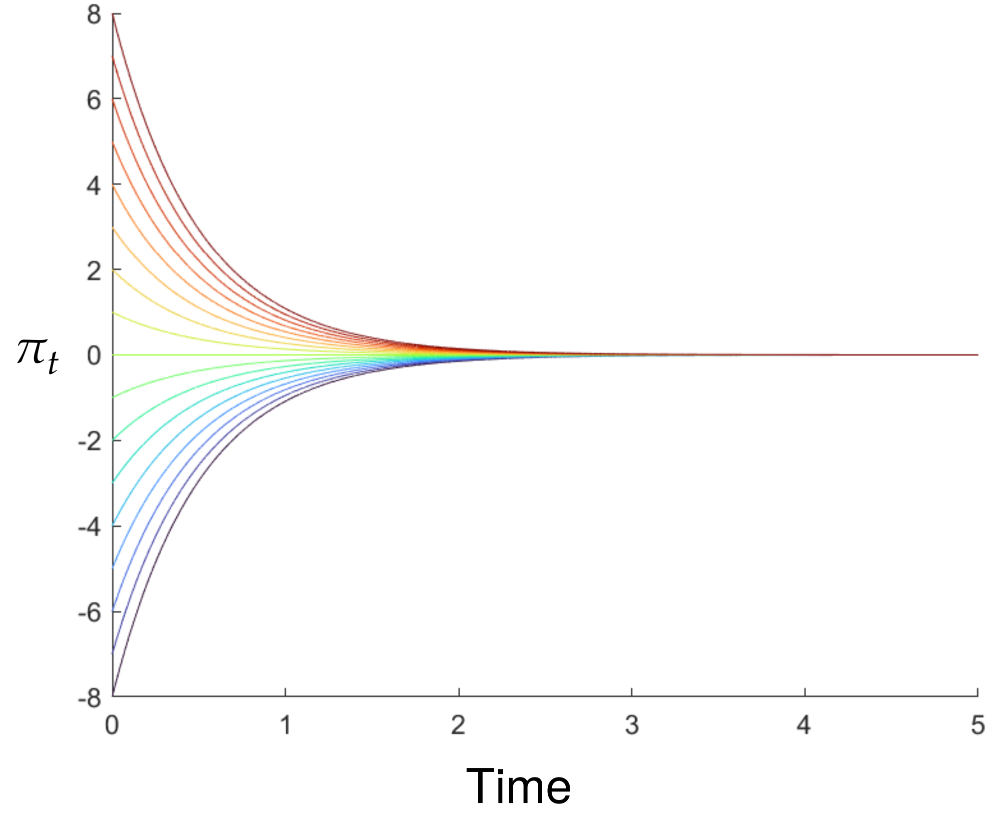
Welfare as a function of inflation

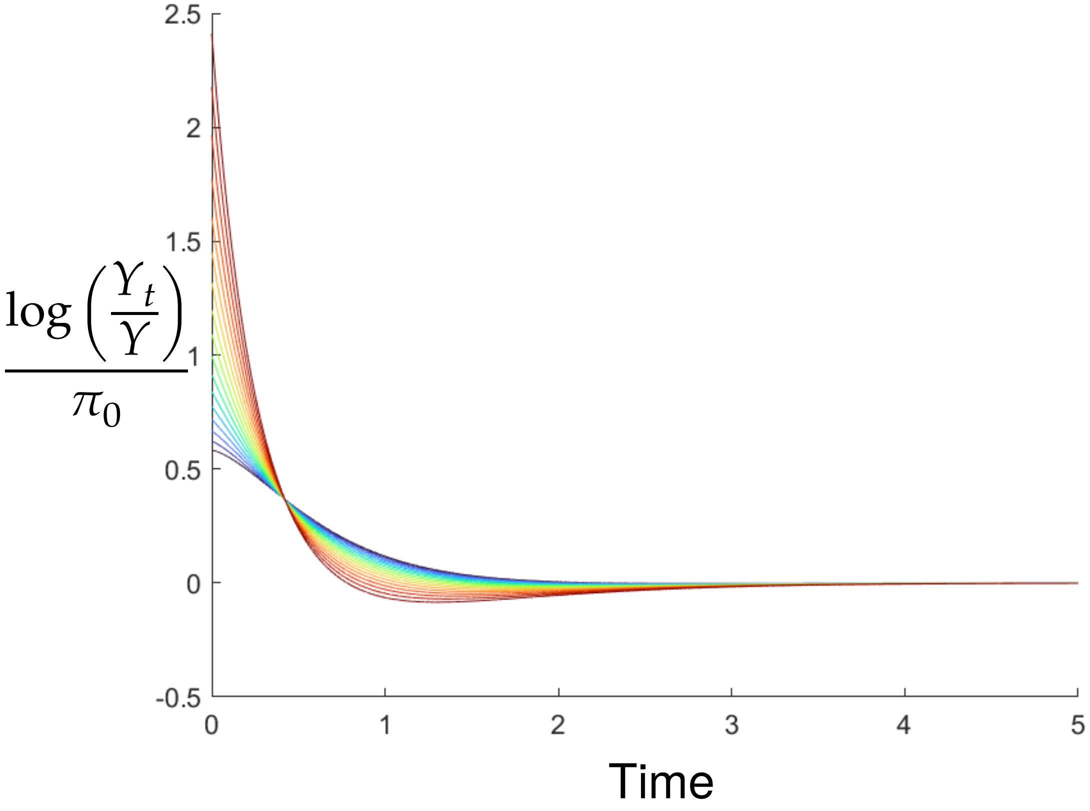


High inflation is bad for welfare without rationing, but it actually improves welfare if rationing is allowed!

Whereas without rationing, high inflation leads to greater distortion, with rationing it reduces misallocation.

IRFs to π shocks (without rationing, without endo. ξ)

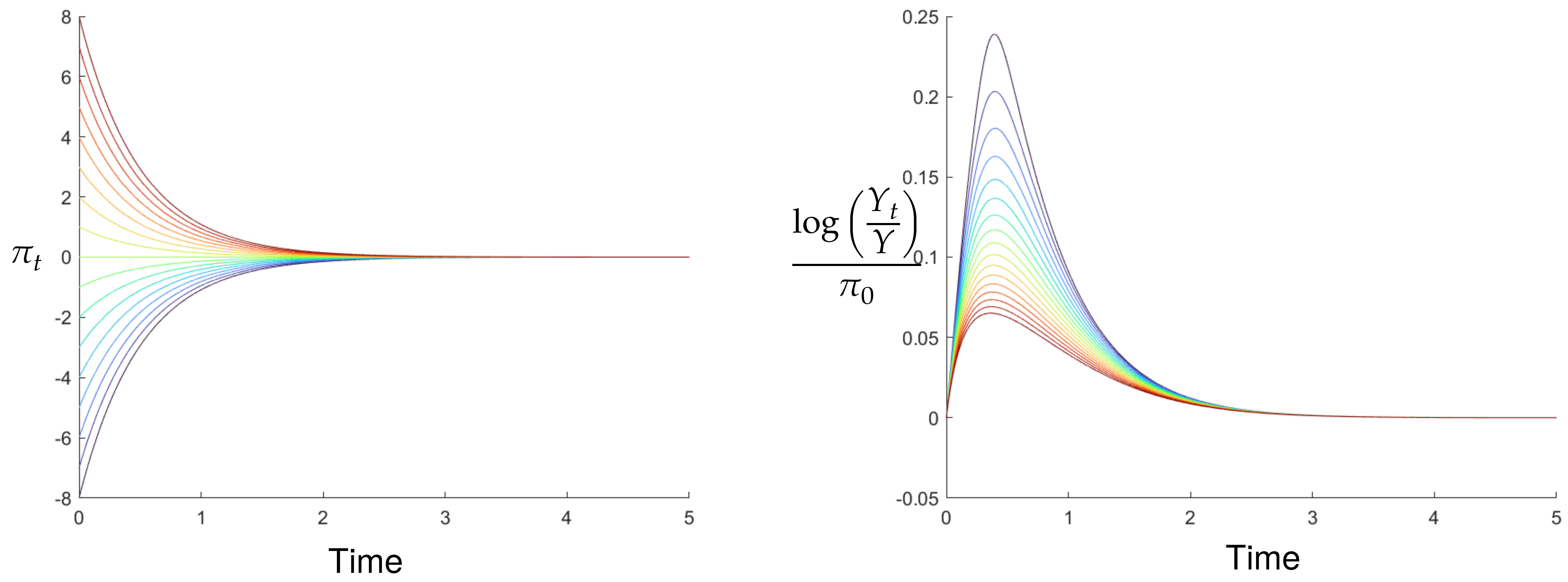




Positive shocks have an amplified effect on output (flat PC). Negative shocks have a dampened impact (steep PC).

Counterfactual!

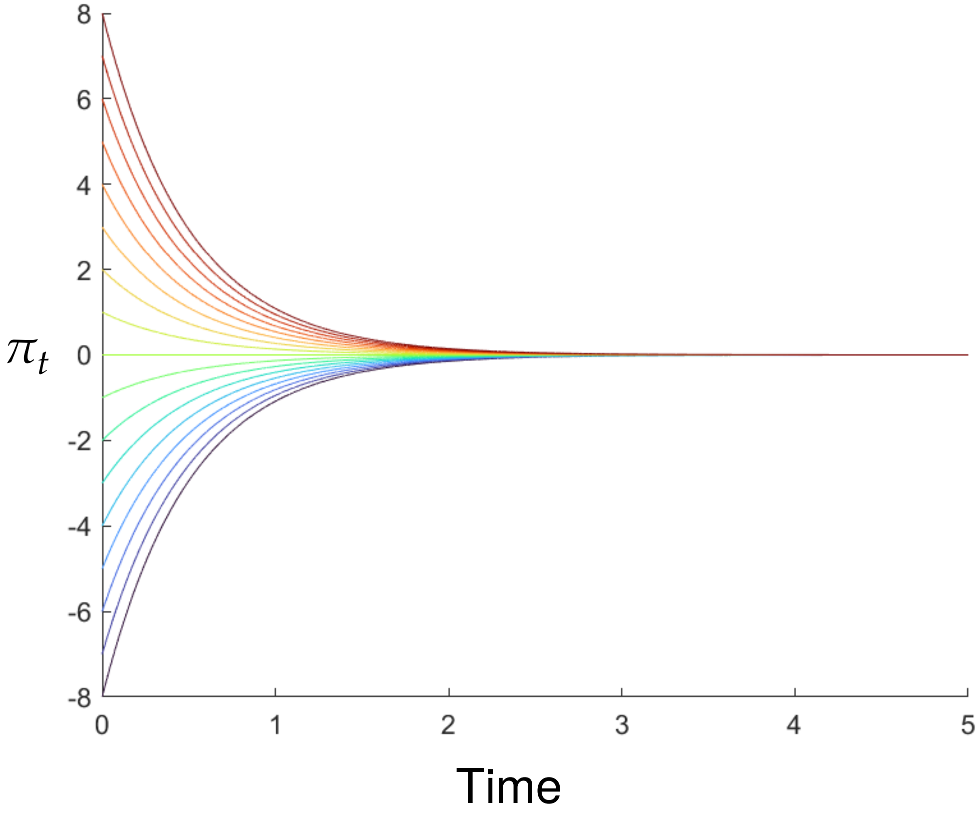
IRFs to π shocks (with rationing, without endo. ξ)

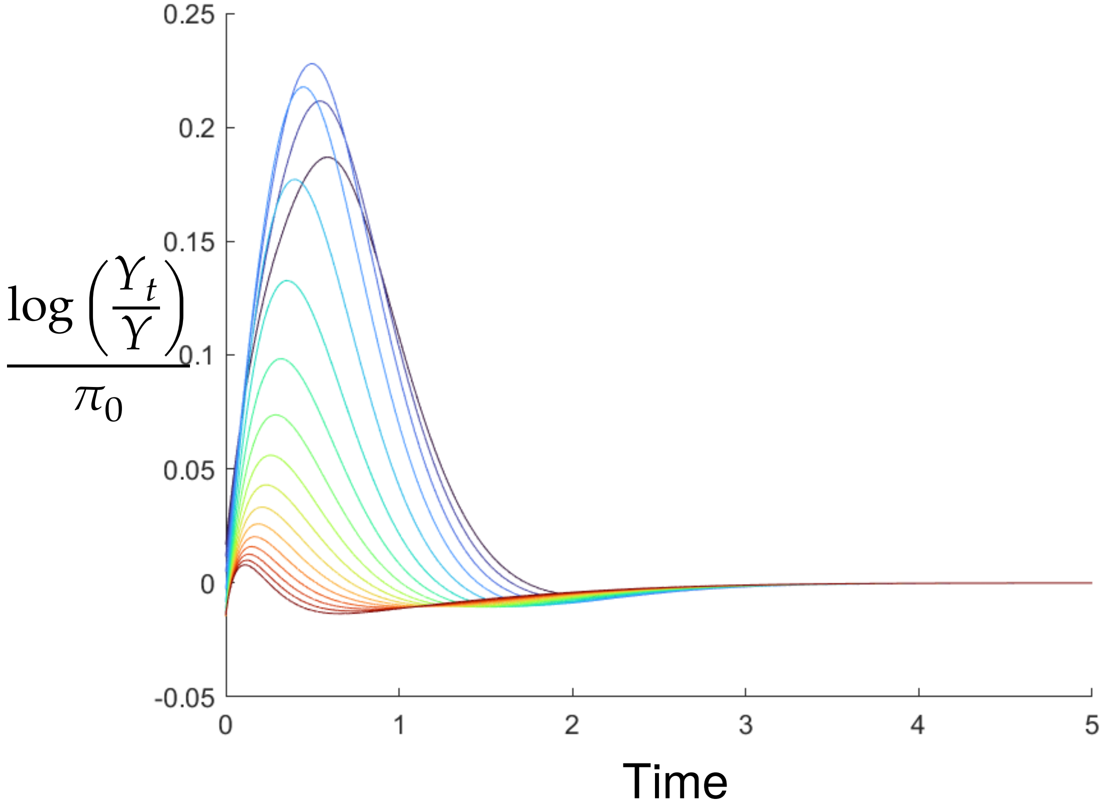


Positive shocks have a dampened effect on output (steep PC). Negative shocks have an amplified impact (flat PC).

As in the data!

IRFs to π shocks (with rationing, with endo. ξ)

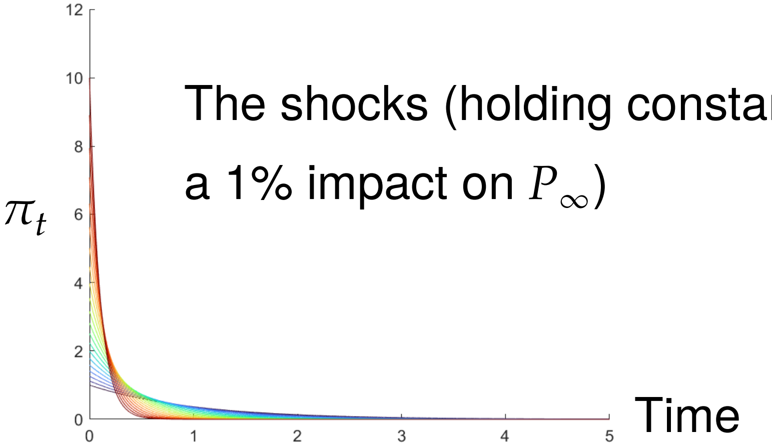


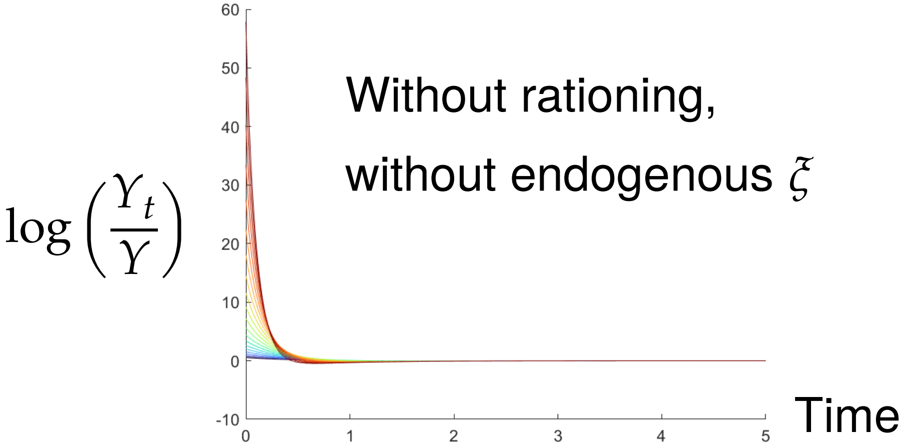


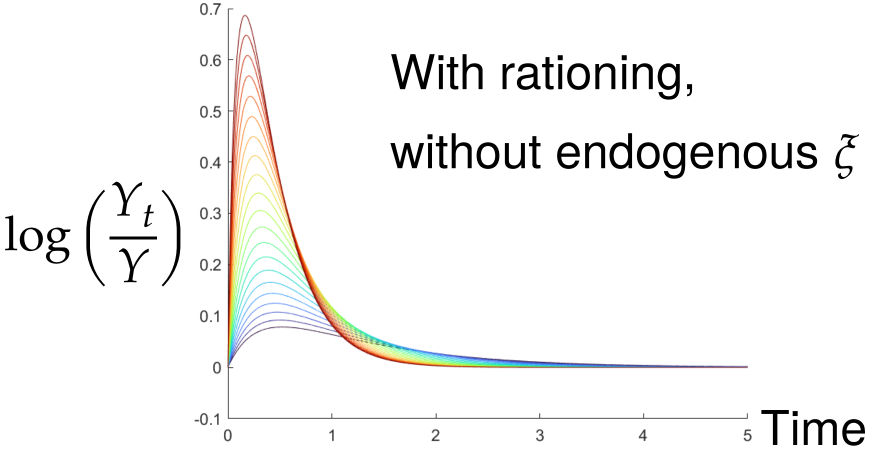
Positive shocks have almost no effect on output (v. steep PC). Negative shocks have an amplified impact (flat PC).

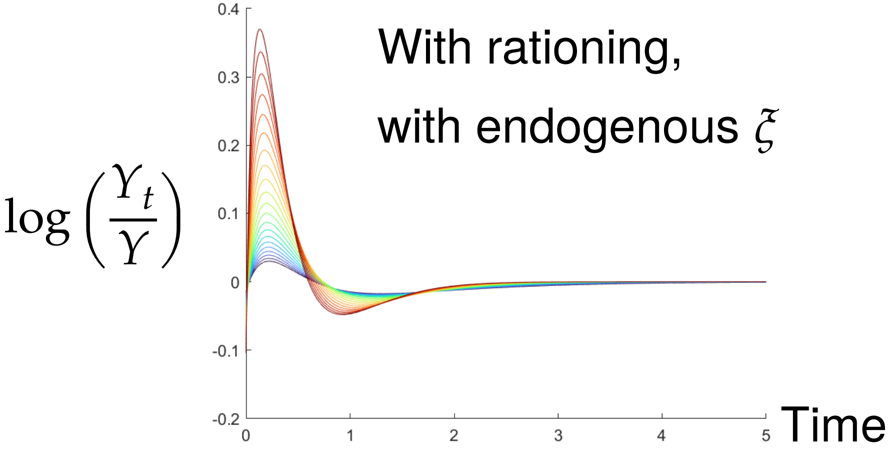
Monetary policy can do harm but not good?

IRFs to π shocks (varying persistence)









Without rationing, jumps in the price level have crazy impacts on output. With rationing, their impact is bounded.

Conclusion

- The standard assumption that firms always satisfy all demand is not innocuous.
- It is responsible for much of the strange behaviour of the non-linear Calvo model.

- Allowing rationing produces a model that fits the data better and performs more reasonably in extreme conditions.
- The model is actually more tractable with rationing than without, so it can be easily scaled to policy models.

- The final paper will have extensions to firm specific capital, partially fixed intermediaries and long-run growth.
- I am interested to hear thoughts on other essential extensions, or crucial empirical results to establish.

Extra slides

Answers to other doubts about rationing

- Why don't firms just change prices, rather than rationing?
    - By revealed preference, firms that can ration make higher profits than firms that cannot. Under rationing, profits always >0.
    - Since profits are higher when rationing is allowed, lower menu (etc.) costs are needed to justify the observed price stickiness.

- Doesn't rationing make output implausibly variable, or implausibly sensitive to conditions?
    - Rationing limits the increase in output following expansionary shocks, actually reducing output variability.
    - Firms can calculate their maximum production quantity before demand realised. Limits on overtime labour not implausible!

Strange properties of the Calvo model

- The Calvo model has some deeply strange properties (Holden, Marsal & Rabitsch 2024).
  - It implies a hard upper bound on steady-state inflation. With standard parameters, this is 5% to 10%.
  - Inflation above this level reduces the output *growth rate* not just the output level, due to ever growing price dispersion.
  - Under standard monetary rules, temporary high inflation can push the economy to this growing price dispersion path.
- These strange properties are tightly linked to the losses made by firms forced to sell at prices below marginal cost.
- When rationing is allowed, these strange properties disappear.
- So it is independently interesting to study rationing even if you do not think it is common at current inflation levels.

The quasi flexible and fully flexible price cases

- The limit as $\xi_t \to \infty$ is not fully flexible prices, as for any ξ_t, firms face all possible ζ before changing price.
- Instead, the limit is quasi flexible prices, which maximize $o_{\tau,t} := \int_0^1 o_{\zeta,\tau,t} g(\zeta)\, d\zeta$.
- If $\frac{\epsilon}{\epsilon-1} \frac{\theta+\epsilon}{\theta+\frac{\epsilon}{1-\alpha}} \leq 1$ then even quasi-flex-price firms ration with positive probability (for all t), meaning $\bar{\zeta}_{\tau,t} < 1$.
  - This condition will hold in my calibration. It would be violated if α was very small, or θ was very large.

- A hypothetical fully flexible price firm would choose its price to maximize $o_{\zeta,\tau,t}$.
- Optimal choice is: $\left(\frac{p_{\zeta,\tau,t}}{P_t}\right)^{1+\epsilon\frac{\alpha}{1-\alpha}} = \frac{\epsilon}{\epsilon-1} \left(\zeta \frac{\theta+1}{\theta}\right)^{\epsilon\frac{\alpha}{1-\alpha}} \frac{\widehat{W}_t}{1-\alpha} Y_t^{\frac{\alpha}{1-\alpha}}$.
- Note that this is increasing in ζ, while the price of a sticky or quasi-flex-price firm is not increasing in ζ.
- Rationing reduces quantities for high ζ, like in the fully flex price case!

State variables and the short-run Phillips curve

- For $j \in \mathbb{N}$, define: $X_{j,t} := \int_{-\infty}^{t} \xi_\tau e^{-\int_\tau^t \xi_\upsilon \, d\upsilon} p_\tau^{\chi_j} \, d\tau$. So: $\dot{X}_{j,t} = \xi_t \left[p_t^{\chi_j} - X_{j,t} \right]$.

- Allowing rationing, total labour demand $L_t := \int_{-\infty}^{t} \xi_\tau e^{-\int_\tau^t \xi_\upsilon \, d\upsilon} \int_0^1 l_{\zeta,\tau,t} g(\zeta) \, d\zeta \, d\tau$ satisfies:

  - $A_t L_t = -\frac{\epsilon}{(1-\alpha)\theta+\epsilon} \left(\frac{\theta}{\theta+1}\right)^{\theta} \left(\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{1}{\alpha}+\frac{\theta}{\epsilon}\frac{1-\alpha}{\alpha}} Y_t^{-\frac{\theta}{\epsilon}} P_t^{-\left(\theta+\frac{1}{\alpha}+\frac{\theta}{\epsilon}\frac{1-\alpha}{\alpha}\right)} X_{1,t} + \left(\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{1}{\alpha}} P_t^{-\frac{1}{\alpha}} X_{2,t}$, with $\chi_1 := \theta + \frac{1}{\alpha} + \frac{\theta}{\epsilon}\frac{1-\alpha}{\alpha}$, $\chi_2 := \frac{1}{\alpha}$.

- Additionally, from the definition of aggregate output, allowing rationing:

  - $1 = -\frac{\epsilon-1}{\theta+\epsilon} \left(\frac{\theta}{\theta+1}\right)^{\theta+1} \left(\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{\theta+\epsilon}{\epsilon}\frac{1-\alpha}{\alpha}} Y_t^{-\frac{\theta+\epsilon}{\epsilon}} P_t^{-\left(\frac{1}{\alpha}+\theta+\frac{\theta}{\epsilon}\frac{1-\alpha}{\alpha}\right)} X_{1,t} + \left(\frac{1-\alpha}{\widehat{W}_t}\right)^{\frac{\epsilon-1}{\epsilon}\frac{1-\alpha}{\alpha}} Y_t^{-\frac{\epsilon-1}{\epsilon}} P_t^{-\frac{\epsilon-1}{\epsilon}\frac{1-\alpha}{\alpha}} X_{3,t}$, with $\chi_{3,1} := \frac{\epsilon-1}{\epsilon}\frac{1-\alpha}{\alpha}$.

- Combined with the household labour FOC, these two equations give a short-run Phillips curve, holding states fixed.

- If rationing is not allowed, the equivalent two equations are:

  - $A_t L_t = \frac{\theta}{\theta+\frac{\epsilon}{1-\alpha}} \left(\frac{\theta+1}{\theta}\right)^{\frac{\epsilon}{1-\alpha}} P_t^{\frac{\epsilon}{1-\alpha}} Y_t^{\frac{1}{1-\alpha}} X_{4,t}$ with $\chi_4 := -\frac{\epsilon}{1-\alpha}$. $1 = \left(\frac{\theta+1}{\theta+\epsilon}\right)\left(\frac{\theta+1}{\theta}\right)^{\epsilon-1} P_t^{\epsilon-1} X_{0,t}$, with $\chi_0 := -(\epsilon-1)$.
  - With $X_{0,t}$ fixed, P_t is fixed. The short-run Phillips curve is horizontal in the NK model without rationing!

Instability without rationing

- We stationarize $X_{j,t}$ by defining $\hat{X}_{j,t} := \frac{X_{j,t}}{P_t^{\chi_{j,1}}}$. And we define: $\hat{p}_t := \frac{p_t}{P_t}$. Then: $\dot{\hat{X}}_{j,t} = \xi_t \hat{p}_t^{\chi_j} - (\xi_t + \chi_j \pi_t)\hat{X}_{j,t}$.

- So: $\xi_t + \chi_j \pi_t$ determines the stability of $\hat{X}_{j,t}$. It is stable if and only if $\xi_t + \chi_j \pi_t > 0$.

- For the model with rationing, we had $\chi_1 = \theta + \frac{1}{\alpha} + \frac{\theta}{\epsilon}\frac{1-\alpha}{\alpha} > 0$, $\chi_2 = \frac{1}{\alpha} > 0$ and $\chi_{3,1} = \frac{\epsilon-1}{\epsilon}\frac{1-\alpha}{\alpha} > 0$. Stability guaranteed!

- For the model without rationing, we had $\chi_4 = -\frac{\epsilon}{1-\alpha} < 0$ and $\chi_0 = -(\epsilon - 1) < 0$.

- If ϵ or α are large enough, then $\xi_t + \chi_4 \pi_t < 0$ or $\xi_t + \chi_0 \pi_t < 0$. Potential instability!

New prices

- For $j \in \mathbb{N}$, define: $z_{j,\tau} := \int_{\tau}^{\infty} e^{-\int_{\tau}^{t} \xi_{\upsilon}\,d\upsilon - \int_{\tau}^{t} r_{\upsilon}\,d_{\upsilon}} \widehat{W}_t^{\omega_{j,2}} Y_t^{\omega_{j,3}} P_t^{\omega_{j,4}}\,dt$, so $\dot{z}_{j,\tau} = -\widehat{W}_t^{\omega_{j,2}} Y_{\tau}^{\omega_{j,3}} P_{\tau}^{\omega_{j,4}} + (\xi_{\tau} + r_{\tau}) z_{j,\tau}$.

- Allowing rationing, updating firms optimally set: $p_{\tau}^{\theta + \frac{\theta}{\epsilon}\frac{1-\alpha}{\alpha}} \propto \frac{z_{2,\tau}}{z_{1,\tau}}$.

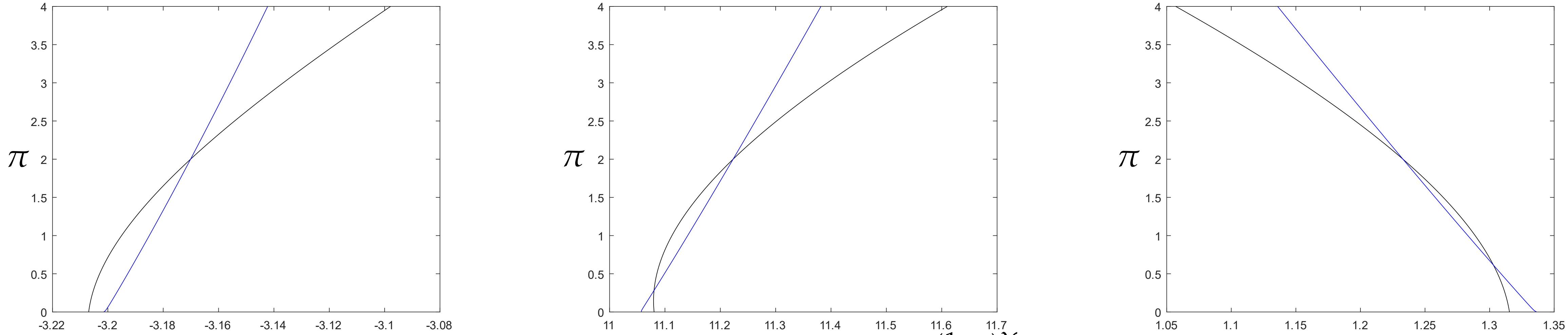
  - Where: $\omega_{1,2} := -\frac{\theta+\epsilon}{\epsilon}\frac{1-\alpha}{\alpha}$, $\omega_{1,3} := -\frac{\theta}{\epsilon}$, $\omega_{1,4} := -\chi_1$, $\omega_{2,2} := -\frac{1-\alpha}{\alpha}$, $\omega_{2,3} := 0$, $\omega_{2,4} := -\chi_2$.

- Without rationing, updating firms optimally set: $p_{\tau}^{1+\epsilon\frac{\alpha}{1-\alpha}} \propto \frac{z_{6,\tau}}{z_{5,\tau}}$.

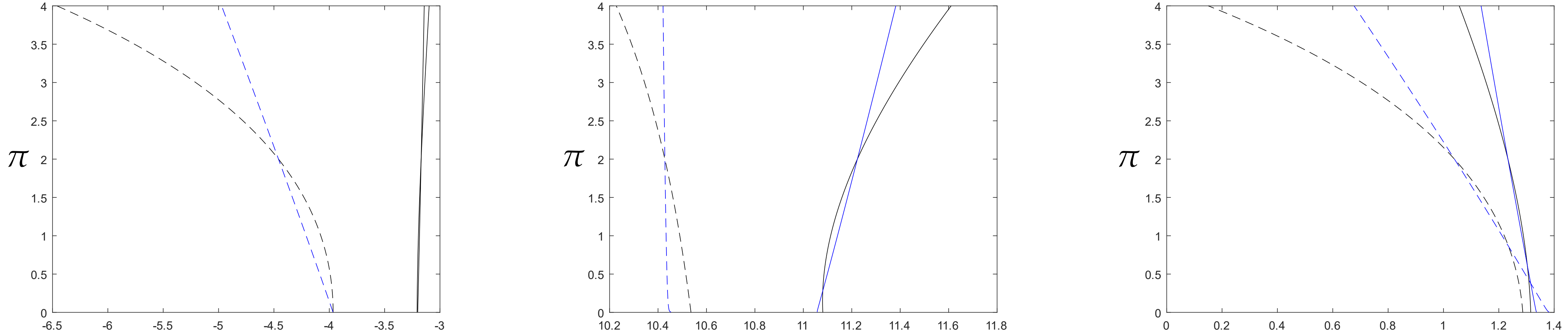
  - Where: $\omega_{5,2} := 0$, $\omega_{5,3} := 1$, $\omega_{5,4} := \epsilon - 1$, $\omega_{6,2} := 1$, $\omega_{6,3} := \frac{1}{1-\alpha}$, $\omega_{6,4} := \frac{\epsilon}{1-\alpha}$.

- We stationarize by defining: $\hat{z}_{j,t} := \frac{z_{j,t}}{P_t^{\omega_{j,4}}}$.

Rationing is good actually (continued!)



Effective TFP (Relative to fully flex) | Aggregate mark-ups: $\log \frac{(1-\alpha)Y}{WL}$ | Excess firm profit share of output



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