Large shocks in menu cost models

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*The view expressed are those of the authors, and do not necessarily reflect the official position of the ECB, the Eurosystem or the Magyar Nemzeti Bank

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  - timing of firms' price adjustments is random
- Claim: similar implications as in more micro-founded menu cost models
  - similarity in terms of aggregate price rigidity
  - firms choose timing of price adjustments

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  - aggregate price is flexible
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  - money essentially neutral
- Midrigan (2011): Yes
  - match leptokurtic shape of Δp-distribution
  - by adding fat-tailed (rather than normal) shocks
  - aggregate price rigidity similar to Calvo
    - selection disappears

Large shocks

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  - calibrated to nominal shocks during normal times

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  - calibrated to nominal shocks during normal times
- What happens if shocks get large?
  - large monetary shocks
  - large devaluations
  - large credit contractions
  - tax changes

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  - match distribution of Δp even better

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  - match distribution of Δp even better
- Analyze model response to large monetary shocks
  - compare with Calvo, Golosov-Lucas and Midrigan
- Use micro data from Hungary to evaluate models
  - Hungary: large, positive and negative (symmetric) tax shocks

Findings

- Aggregate price flexibility Figure
  - fraction of adjusters quickly increases with shock size
    - $\Longrightarrow$ inflation PT also increases quickly
  - model with fat tailed shocks more flexible
    - opposite of Midrigan's small shock result

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- Asymmetry Figure
  - asymmetric inflation PT for positive and negative shocks
  - if there is trend inflation (small, 2% per year enough)
  - negative shock: inflation takes care of price decreases
  - model with fat tailed shocks more asymmetric

Findings *(cntd)*

- Quantitative predictions of different models (in terms of aggregate price flexibility and asymmetry)
  - baseline model quite close to data
  - normal model (GL) underestimates both
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- Implication for small shocks
  - baseline model is NOT similar to Calvo!
  - Golosov-Lucas-type selection is back

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- Large and symmetric aggregate shocks
  - affected different products
  - use processed food sector
    - increase- and decrease-affected products similar Moments

Effects of VAT-changes

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  - normal times (no tax change): 13.5%
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  - aggregate price flexibility and asymmetry
- Which sticky price model can predict this?
  - Calvo surely not
    - neither flexible nor asymmetric
  - any of the menu cost models?

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  - representative household
  - heterogenous firms
  - central bank and government (money growth and tax rates)

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- Central bank and government
  - passive: keep money growth (g_M) and VAT-rate (τ_t) fixed
  - unexpected change in money growth rate / VAT
    - possibly pre-announced

Heterogenous firms

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- Why have idiosyncratic productivity shocks?
  - to match large size of price changes in data
  - aggregate shocks with small inflation rate could not do this

Heterogenous firms (*cntd*)

- Productivity innovation $\varepsilon_t(i)$ is mixed normal

$$\varepsilon_t(i) = \begin{cases} N(0, \sigma^2/\lambda) & \text{with probability } p \\ N(0, \sigma^2) & \text{with probability } 1-p \end{cases}$$

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  - poisson innovations a la Midrigan (2011) ($\lambda = \infty$)
- Firms solve a dynamic problem of whether or not to change price Equations
  - problem stationary in productivity adjusted relative price: $p_t(i) = \frac{P_t(i)A_t(i)}{P_t}$

Equilibrium and numerical solution

- Standard equilibrium Details
  - agent maximize, given their information
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  - agent maximize, given their information
  - markets clear
- Numerical solution
  - no aggregate uncertainty (tax, money growth rates fixed)
  - steady state: global heterogenous agents methods Details
  - transition dynamics: shooting Details

Data

- Store-level monthly price data on processed food products
  - 128 different products
  - 123 stores/product on average
  - time span: 2001 December – 2006 December
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- Matched moments (4)
  - frequency of price changes
  - average absolute size of price changes
  - kurtosis of price change size distribution
  - interquartile range of absolute size distribution

Calibration

- Pre-selected parameters
  - $\theta = 5$ (elasticity of substitution)
  - $\beta = 0.96^{1/12}$ (time preference)
  - $g_M = \pi = 4.2\%/12$ (inflation/money growth rate)
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- Model variants Calibrated parameters
  - baseline (**mixed** normal)
  - **normal** model of Golosov-Lucas ($p = 0$)
  - **poisson** model of Midrigan ($\lambda = \infty$)

Unmatched moments

Moments at the months of tax changes

Unmatched moments	Data	Mixed	Poisson	Normal	Calvo
Frequency tax incr	62.0%	61.1%	90.1%	24.7%	13.5%
Frequency tax decr	26.9%	24.0%	13.7%	17.6%	13.5%
Avg abs size tax incr	9.0%	7.9%	7.4%	10.7%	10.8%
Avg abs size tax decr	8.6%	7.9%	9.4%	10.5%	9.7%
Inflation PT tax incr	98.9%	94.2%	138.7%	49.1%	10.1%
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  - Size distributions
- Poisson: overestimates asymmetry
- Normal: underestimates asymmetry, frequency effect

Step by step

- Understand differences in basic menu cost models
  - no trend inflation
    - no asymmetry
  - no pre-announcement

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- Add pre-announcement
  - here we arrive to the calibrated version
- Extend analysis to multi-product case
  - introduces some very small price changes into model
  - qualitative results do not change
  - fit of Δp-distribution even better

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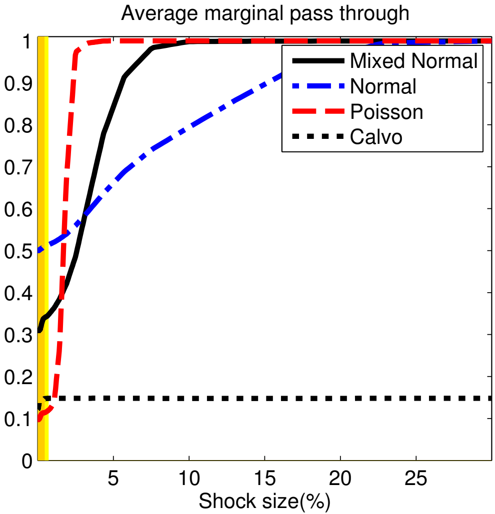
- Understand differences by analyzing
  1. distribution of desired price changes
     - Δp-distribution if price change was temporarily free
  2. inaction bands
     - for small price changes, gains of change $<$ menu cost

Step 1: no trend inflation / pre-announcement

Relationship between shock size and inflation PT



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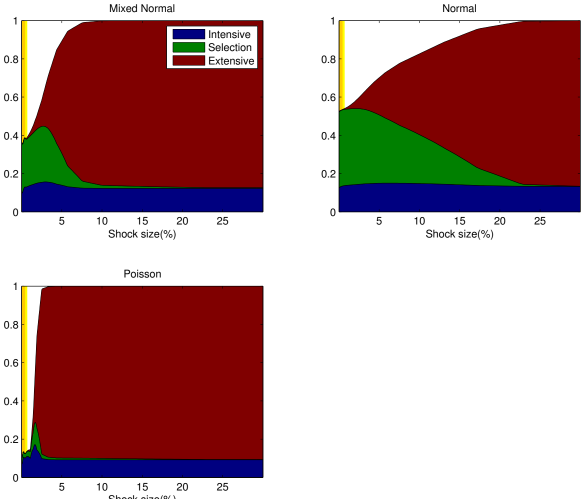
Decomposition of PT: extensive margin dominates for large shocks



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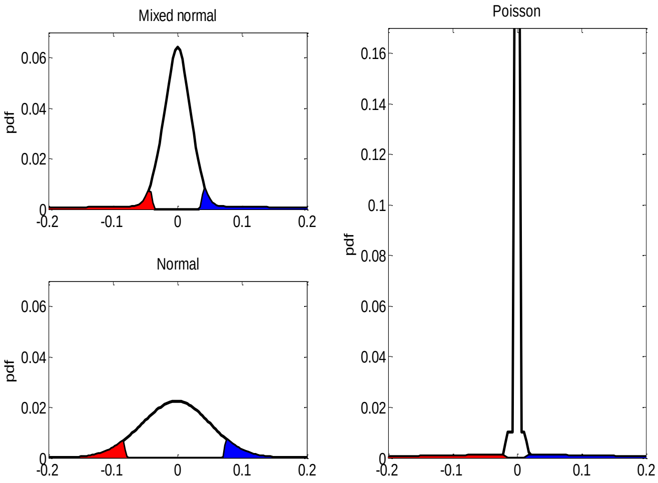
Steady-state desired price change distributions



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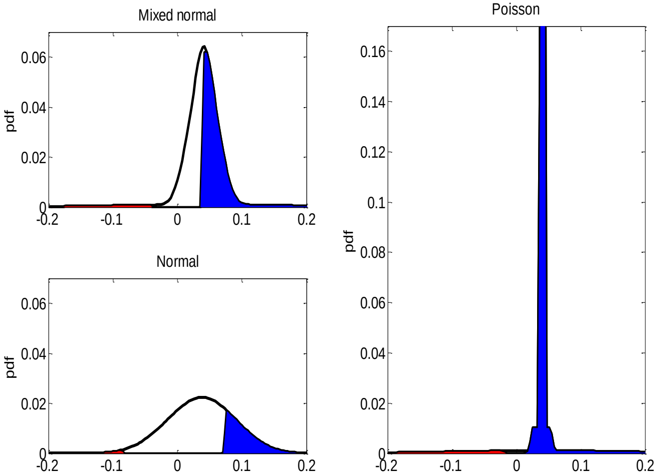
Desired price change distributions when a shock hits



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- For large shocks, extensive margin effect dominates
- Extensive margin effect: shape of desired distribution matters!

Step 2: Add trend inflation

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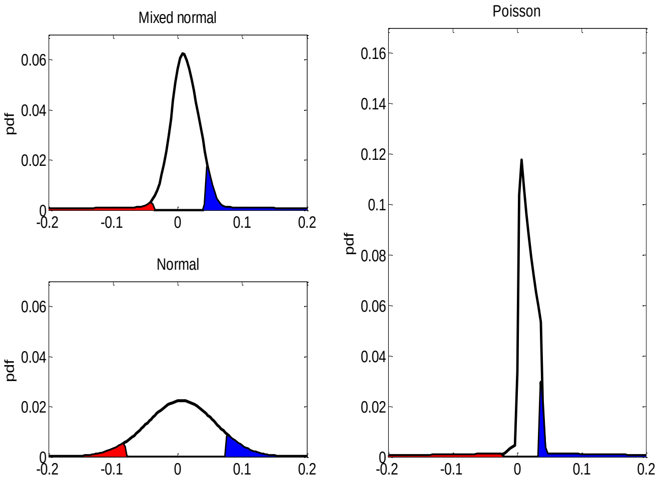

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  - this leads to asymmetry in reaction to shocks Asymmetry
- Resulting asymmetry is driven by the asymmetry of extensive margin effect Decomposition
  - again, shape of desired distribution matters

Step 3: add pre-announcement

Effect of pre-announcement in mixed normal model

		Announcement lead			
Unmatched moments	**data**	**0 mth**	**1 mth**	**3 mth**	**5 mth**
Frequency tax incr	62.0%	66.2%	64.1%	**61.1%**	60.8%
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Initial infl PT tax incr	–	–	1.2%	**4.4%**	5.0%
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- Pre-announcement increases asymmetry
  - positive shock: firms know they will adjust when shock hits (freq around 60%), so few does anything initially
  - negative shock: firms will not adjust when shock hits (freq around 30%), so tend to adjust in advance

Conclusion

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  - leptokurtic shock distribution with many 0-s
    - many "very small" innovations not enough
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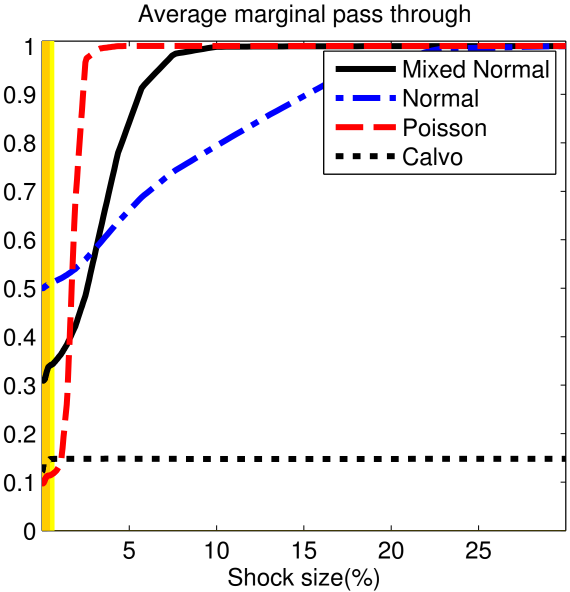
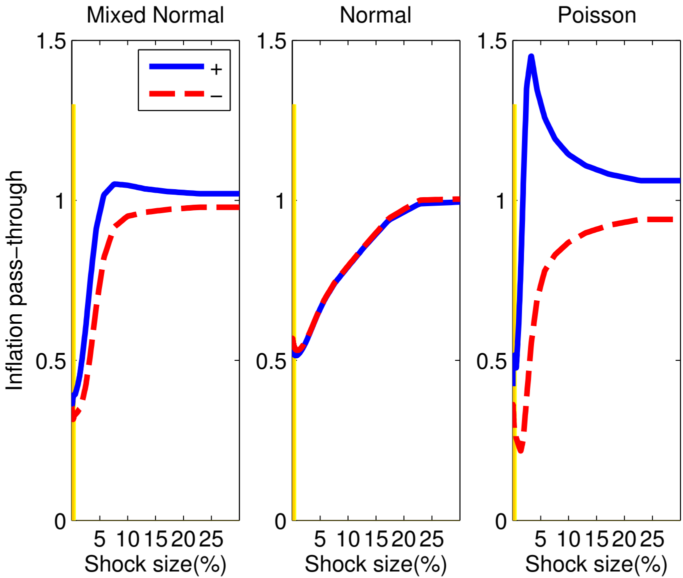
- Takeaway: menu cost-type nominal rigidities are not enough to generate realistic aggregate price rigidity
  - what else? $\longrightarrow$ future research

Inflation PT for different shock sizes



Asymmetric inflation PT for different shock sizes



Moments of products in the two VAT brackets

Moments	**-5%**	**+5%**
Frequency (no tax, NT)	12.3%	13.8%
	(1.1%)	(0.5%)
Avg abs size (NT)	10.8%	9.7%
	(0.6%)	(0.2%)
Kurtosis (NT)	3.96	3.98
	(0.003)	(0.001)
Interquartile range (NT)	8.3%	8.1%
	(0.01%)	(0.01%)

Household utility and first-order conditions

- utility function

$$\max_{\{C_t(i), L_t, M_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \frac{\mu}{1+\psi} L_t^{1+\psi} + \nu \log \frac{M_t}{P_t} \right)$$

- Euler equation

$$\frac{1}{R_t} = \beta E_t \frac{P_t C_t}{P_{t+1} C_{t+1}}$$

- Relative demands (Dixit-Stiglitz):

$$C_i(t) = \left(\frac{P_i(t)}{P(t)} \right)^{-\theta} C(t)$$

- Labor supply equation

$$\mu L_t^{\psi} C_t = W_t / P_t$$

- Money demand

$$\frac{M_t}{P_t} = \nu C_t \frac{R_t}{R_t - 1}$$

Firms dynamic problem

- normalized profit function (w_t real wage)
  $\Pi\left(p_t(i), w_t, \tau_t\right) = \frac{p_t(i)^{1-\theta}}{1+\tau_t} - w_t p_t(i)^{-\theta}$

- firm value if it changes price
  $V^C\left(\Omega_t\right) =$
  $\max_{p_t^*(i)} \left\{ \Pi(p_t^*(i), w_t, \tau_t) - \phi + \beta E_t V\left(p_t^*(i) e^{\varepsilon_{t+1}(i)}, \Omega_{t+1}\right) \right\}$
  - $\Omega_t = (\tau_t, w_t, \pi_t, \Gamma_t)$ vector of aggregate state variables
  - Γ_t firm distribution w.r.t. $p_t(i)$

- firm value if does not change price
  $V^{NC}\left(p_{t-1}(i), \Omega_t\right) = \Pi\left(\frac{p_{t-1}(i)}{(1+\pi_t)}, w_t, \tau_t\right) + \beta E_t V\left(\frac{p_{t-1}(i)}{(1+\pi_t)} e^{\varepsilon_{t+1}(i)}, \Omega_{t+1}\right)$

- firm value
  $V\left(p_{t-1}(i), \Omega_t\right) = \max_{\{C,NC\}} \left[V^{NC}\left(p_{t-1}(i), \Omega_t\right), V^C\left(\Omega_t\right)\right]$

Equilibrium

1. Household maximizes utility subject to budget constraint taking prices, wages as given
2. Firms set nominal prices to maximize their value functions, taking their relative prices and idiosyncratic technology, and the future path of aggregate variables as given.
3. Money supply growth is constant; taxes are fixed.
4. Market clearing in the goods, bond, labor markets.

Numerical solution: Steady state

- No aggregate uncertainty (g_M, τ are fixed)
- Aggregate endogenous variables are constant
- Iteration in w
  1. Guess a value w_0
  2. Solve for value and policy functions under w_0
  3. Calculate equilibrium distribution of firms over their idiosyncratic state variable ($p_{-1}(i)$)
  4. Adjust w_0 to make mean relative price zero.

Numerical solution: Transitional dynamics

- One time permanent shock to g_{PY} or τ
  - Shooting
  - Assume new SS reached in T periods
  - Iterate on inflation path
    1. Guess inflation path $\{\pi_1, \pi_2, ..., \pi_T\}$
    2. Calculate value- and policy functions
    3. Obtain resulting inflation path
    4. Do until convergence in paths

Calibrated parameters

Parameters	**Mixed normal**	**Poisson**	**Normal**
ϕ	0.78%	0.46%	2.05%
σ_ε	4.41%	4.55%	3.67%
p	0.903	0.898	0
λ	145	∞	–

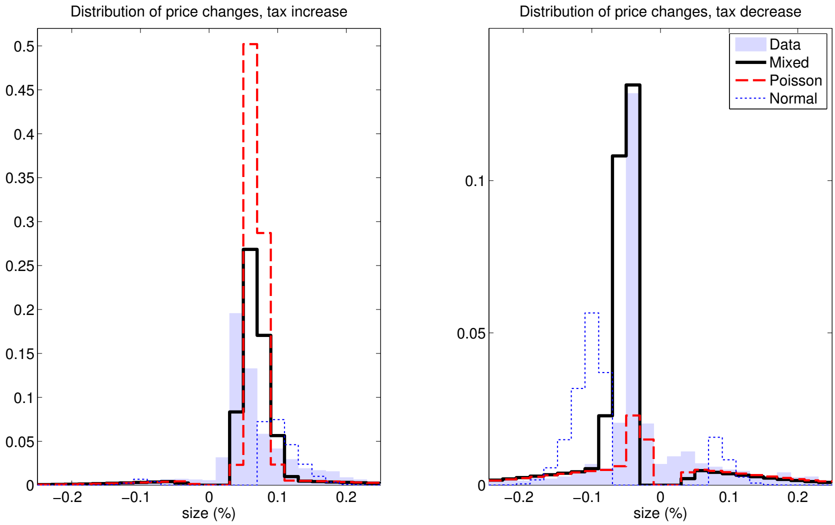
Mixed normal

$$\varepsilon_t(i) = \begin{cases} N(0, \sigma = 1.14\%) & \text{with probability } 0.903 \\ N(0, \sigma = 13.73\%) & \text{with probability } 0.097 \end{cases}$$

Poisson

$$\varepsilon_t(i) = \begin{cases} N(0, \sigma = 0\%) & \text{with probability } 0.898 \\ N(0, \sigma = 14.26\%) & \text{with probability } 0.102 \end{cases}$$

Price change distributions when shocks hit

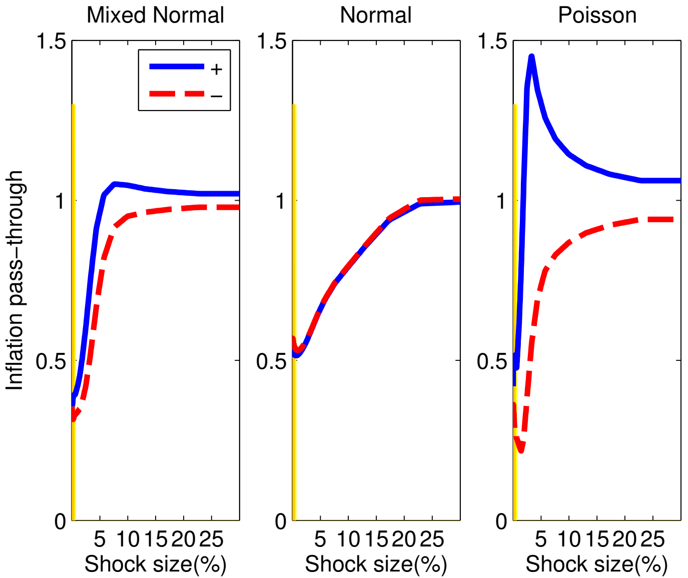


Inflation PT and its decomposition

- marginal PT at time t: $\gamma_t = \frac{\pi_t - \bar{\pi}}{(1 - \sum_{i=0}^{t-1} \gamma_i)\Delta m_0}$
- main PT measure is (weighted) average marginal PT: $\bar{\gamma} = \sum_{t=1}^{T} w_t \gamma_t$
  - weights $w_t = (\pi_t - \bar{\pi})/\Delta m_0$
- decomposition of PT

$$\frac{\pi_t - \pi}{\Delta m_0} = \underbrace{\frac{\Delta \bar{x}^* \bar{\lambda}}{\Delta m_0}}_{\text{intensive}} + \underbrace{\frac{\Delta \bar{\lambda} \bar{x}^* + \Delta \bar{\lambda} \Delta \bar{x}^*}{\Delta m_0}}_{\text{extensive}} + \underbrace{\frac{\Delta \int_{p_{-1}} (x^* - \bar{x}^*) \lambda \psi}{\Delta m_0}}_{\text{selection}}$$

Asymmetric inflation PT under trend inflation



Decomposing asymmetry under trend inflation