Pricing models

Ludwig Straub

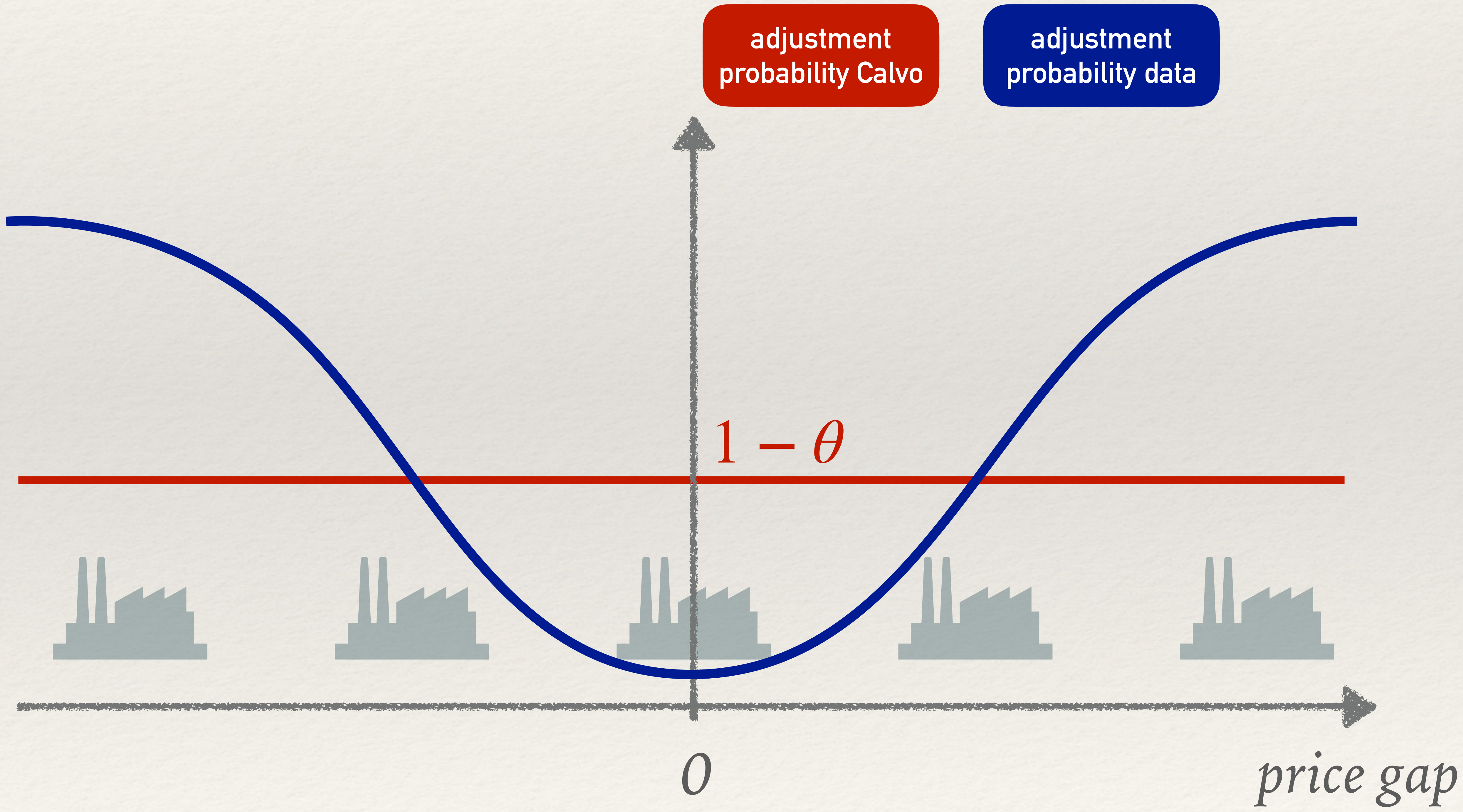
NBER Heterogeneous Agents Workshop, 2025

Based on project with Adrien, Matt, and **Rodolfo Rigato (ECB)**

The New-Keynesian Phillips Curve

$$\pi_t = \kappa \widehat{mc}_t + \beta \mathbb{E}_t \pi_{t+1}$$

- Built on strong assumptions:
  - Rotemberg or **Calvo pricing**
  - Not in line with **micro data**!
- **Not in line with macro data either!**
  - no inertia, too forward looking
  - slope κ too high!



Can we do better?

- Lots of research on **menu cost models**

  [Bils-Klenow, Nakamura-Steinsson, Gertler-Leahy, Klenow-Kryvtsov, Golosov-Lucas, Midrigan, Alvarez-Lippi, Vavra, Karadi-Schoenle-Wursten,…]

  - firms can always adjust, just need to pay a cost

- … but what is the **Phillips curve with menu cost models**?

- What does "Phillips curve" even mean with menu cost models?

Can we do better?

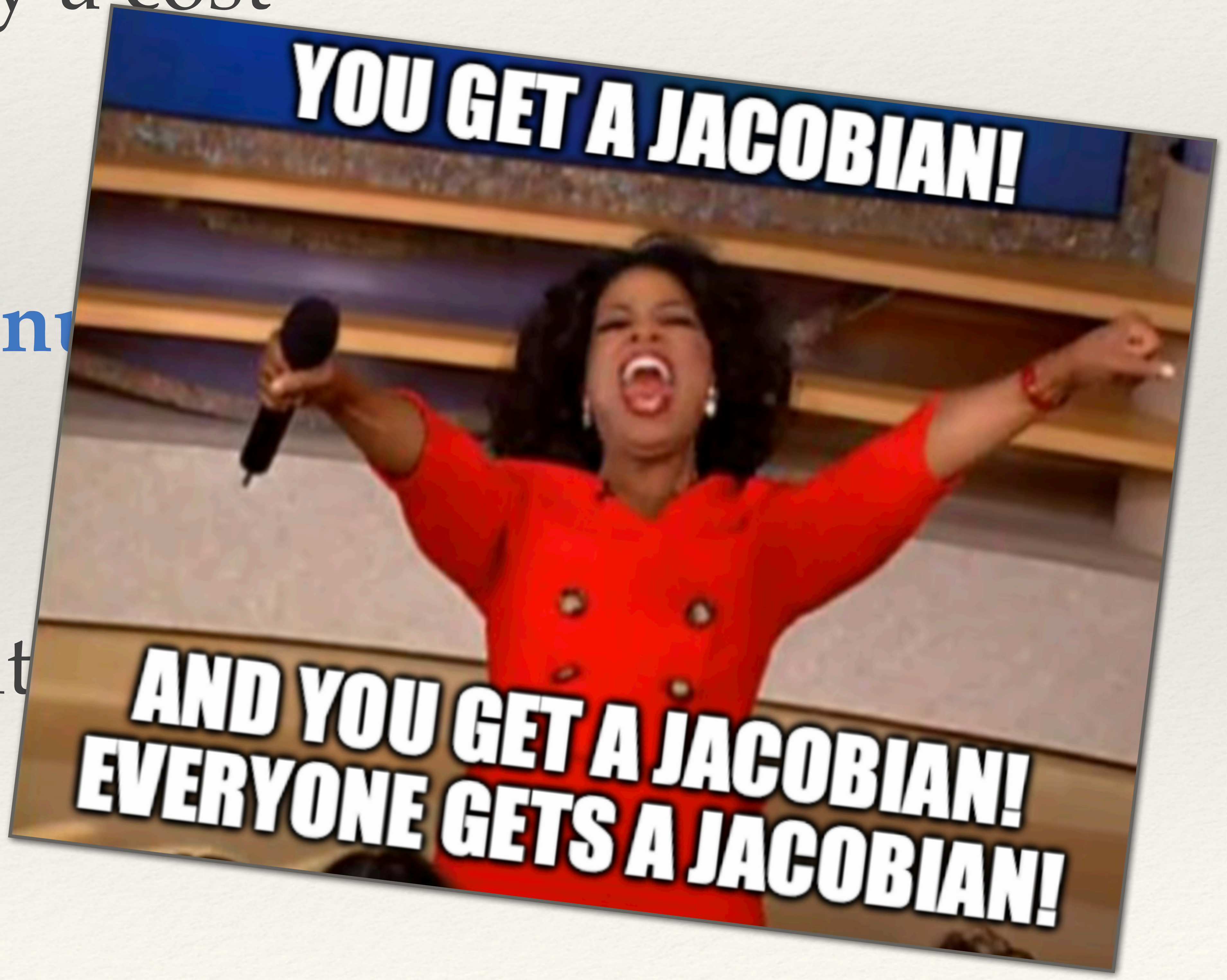
- Lots of research on **menu cost models**

  [Bils-Klenow, Nakamura-Steinsson, Gertler-Leahy, Klenow-Kryvtsov, Golosov-Lucas, Midrigan, Alvarez-Lippi, Vavra, Karadi-Schoenle-Wursten,…]

  - firms can always adjust, just need to pay a cost

- … but what is the **Phillips curve with menu**

- What does "Phillips curve" even mean wit



Warm-Up: What is a "Phillips curve"?

$$\{\widehat{mc}_t\} \longrightarrow \{\pi_t\}$$

This is the heart of the Phillips curve!

$$\begin{tikzcd} \{\widehat{MC}_t\} \arrow[r, bend left] & \{\widehat{P}_t\} \arrow[l, bend left] & \Longleftrightarrow \{\pi_t\} \end{tikzcd}$$

$$\widehat{MC}_t = \widehat{mc}_t \, \widehat{P}_t$$

Two crucial Jacobians

- **Pass-Through Matrix** (this is what is at the heart of the Phillips curve)

$$\hat{\mathbf{P}} = \boldsymbol{\Psi} \cdot \widehat{\mathbf{MC}}$$

- **Generalized Phillips Curve**

$$\hat{\boldsymbol{\pi}} = \mathbf{K} \cdot \widehat{\mathbf{mc}}$$

- We can derive $\mathbf{K}$ from $\boldsymbol{\Psi}$ …

$$\mathbf{K} = (\mathbf{I} - \mathbf{L})(\mathbf{I} - \boldsymbol{\Psi})^{-1}\boldsymbol{\Psi}$$

Calvo model

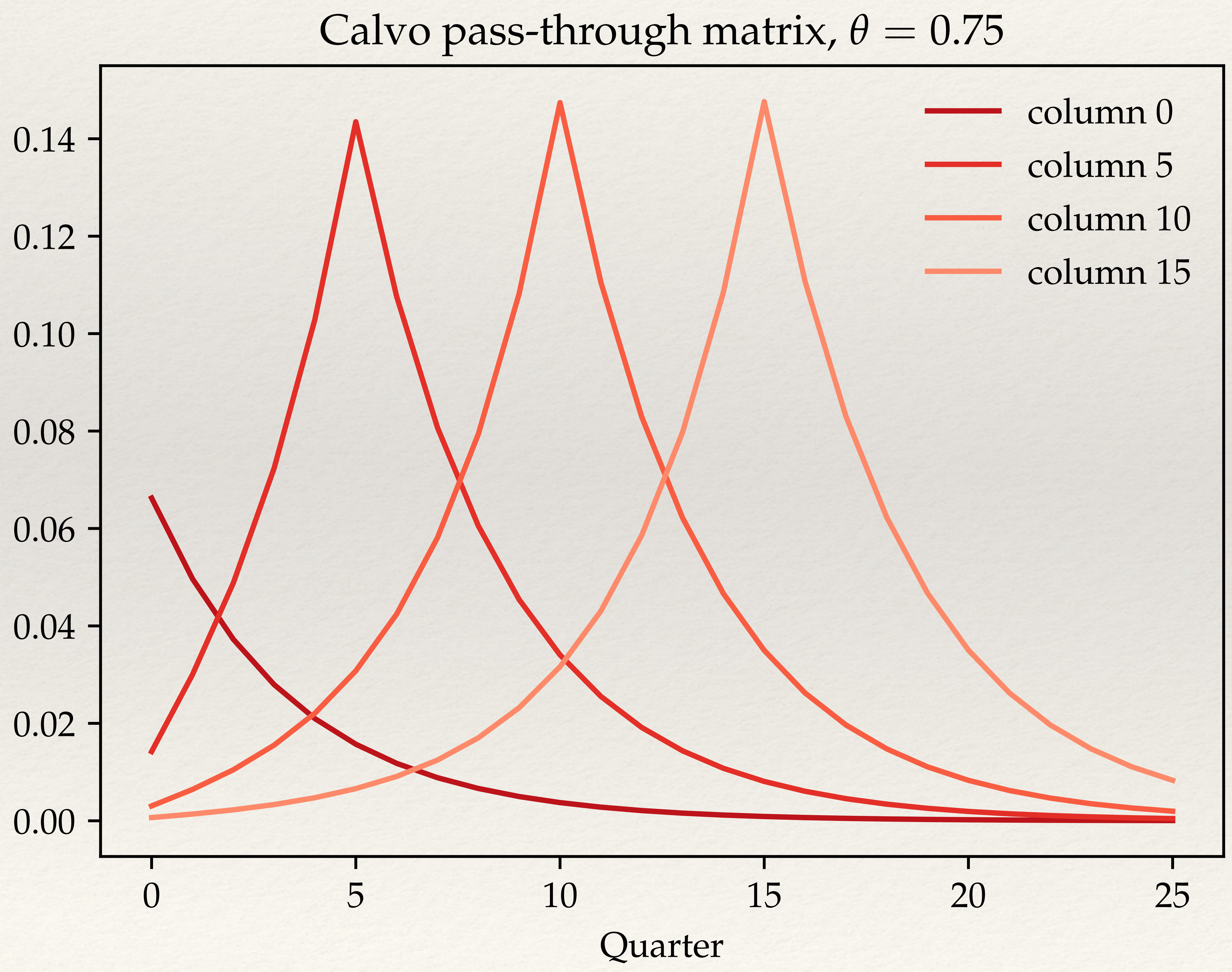
$$\Psi \equiv (1-\theta)\begin{pmatrix} 1 & 0 & 0 & \cdots \\ \theta & 1 & 0 & \cdots \\ \theta^2 & \theta & 1 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix} \cdot \left(1-\beta\theta\right)\begin{pmatrix} 1 & \beta\theta & \left(\beta\theta\right)^2 & \cdots \\ 0 & 1 & \beta\theta & \cdots \\ 0 & 0 & 1 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

$$\mathbf{K} = \begin{pmatrix} \kappa & \beta\kappa & \beta^2\kappa & \cdots \\ 0 & \kappa & \beta\kappa & \cdots \\ 0 & 0 & \kappa & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix} \qquad \kappa = \frac{(1-\theta)\left(1-\beta\theta\right)}{\theta} \qquad \Leftrightarrow \qquad \pi_t = \kappa \widehat{mc_t} + \beta \mathbb{E}_t \pi_{t+1}$$

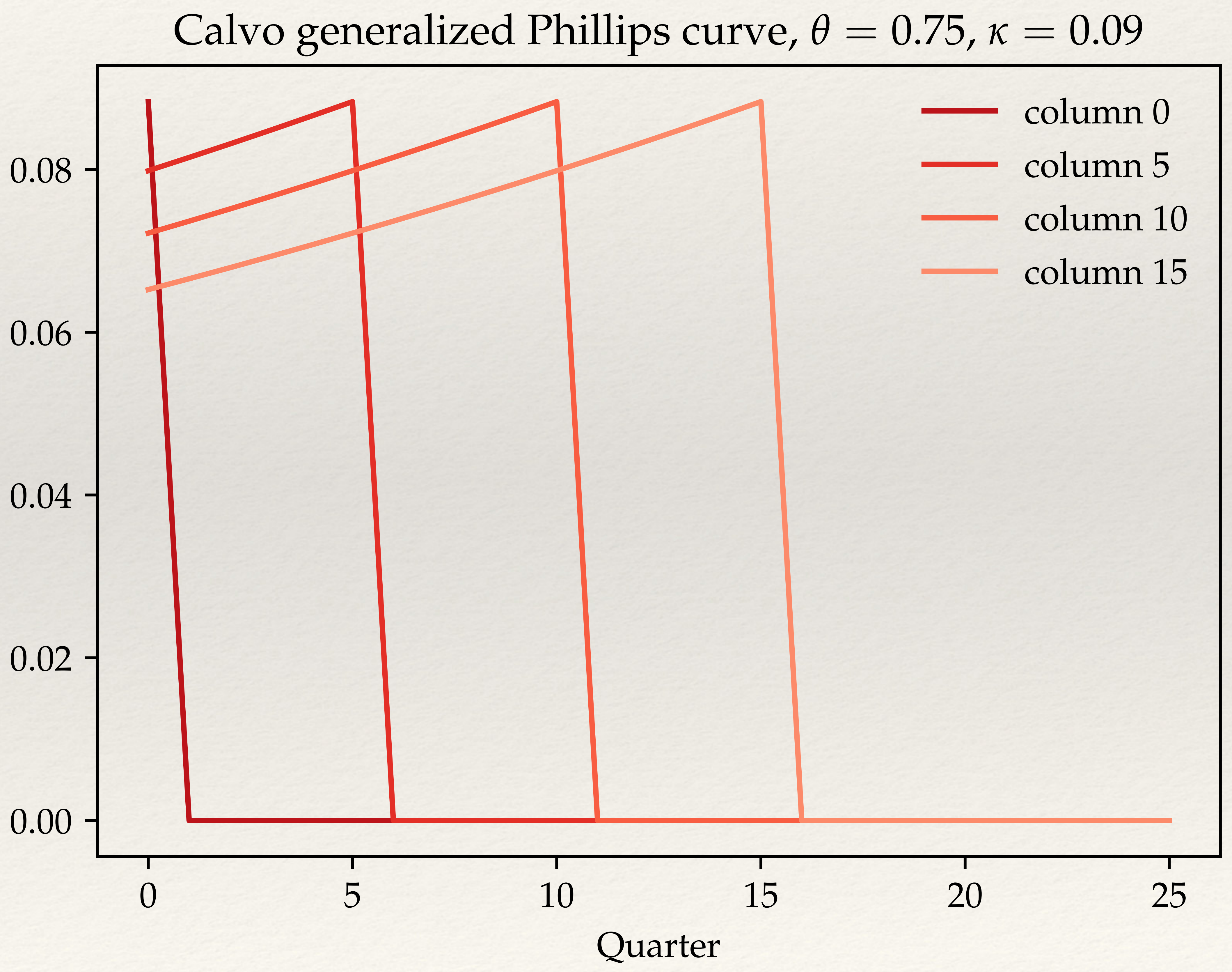
Special case of a "time dependent" model with exponential "survival function" θ^t

Calvo model

Ψ

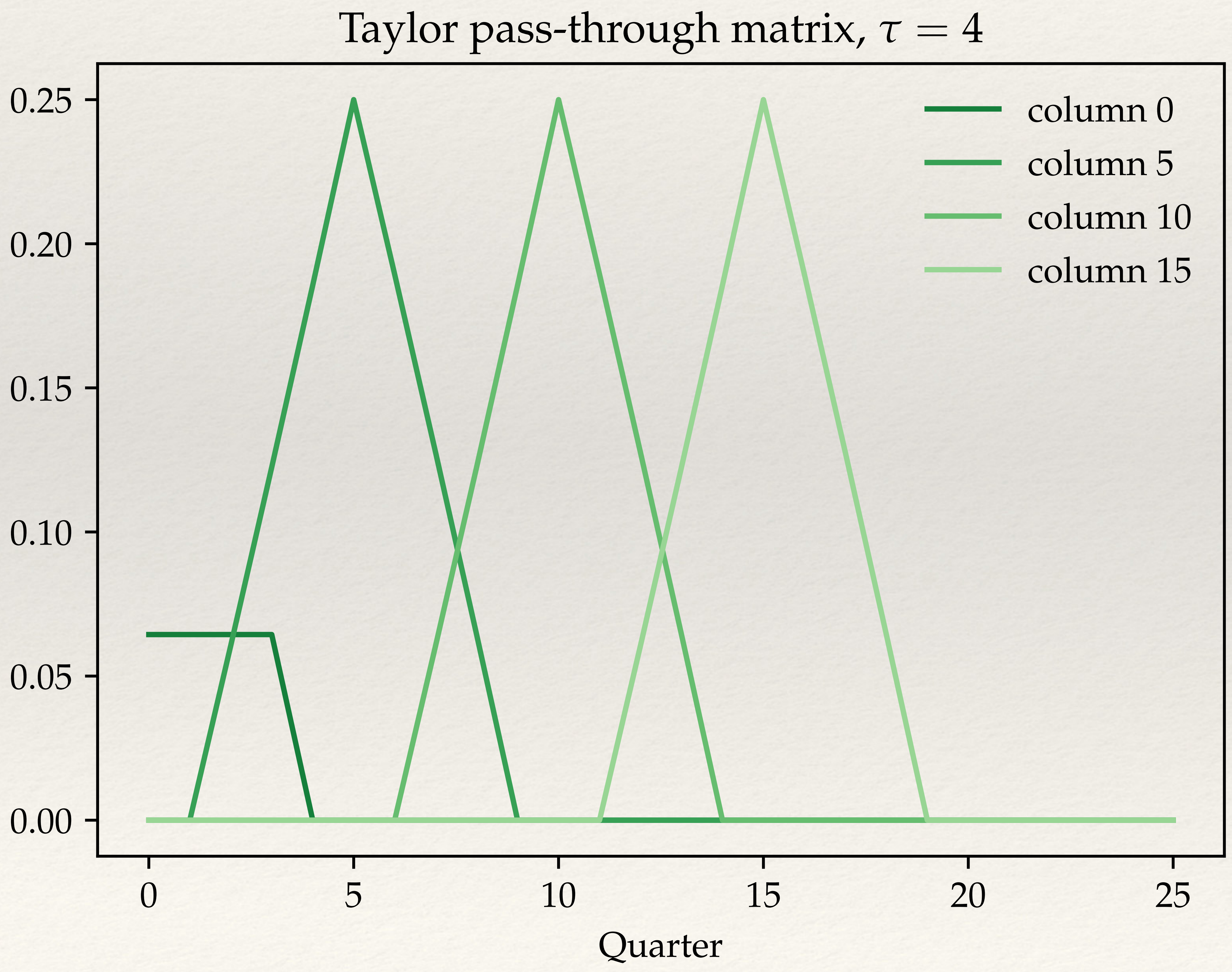


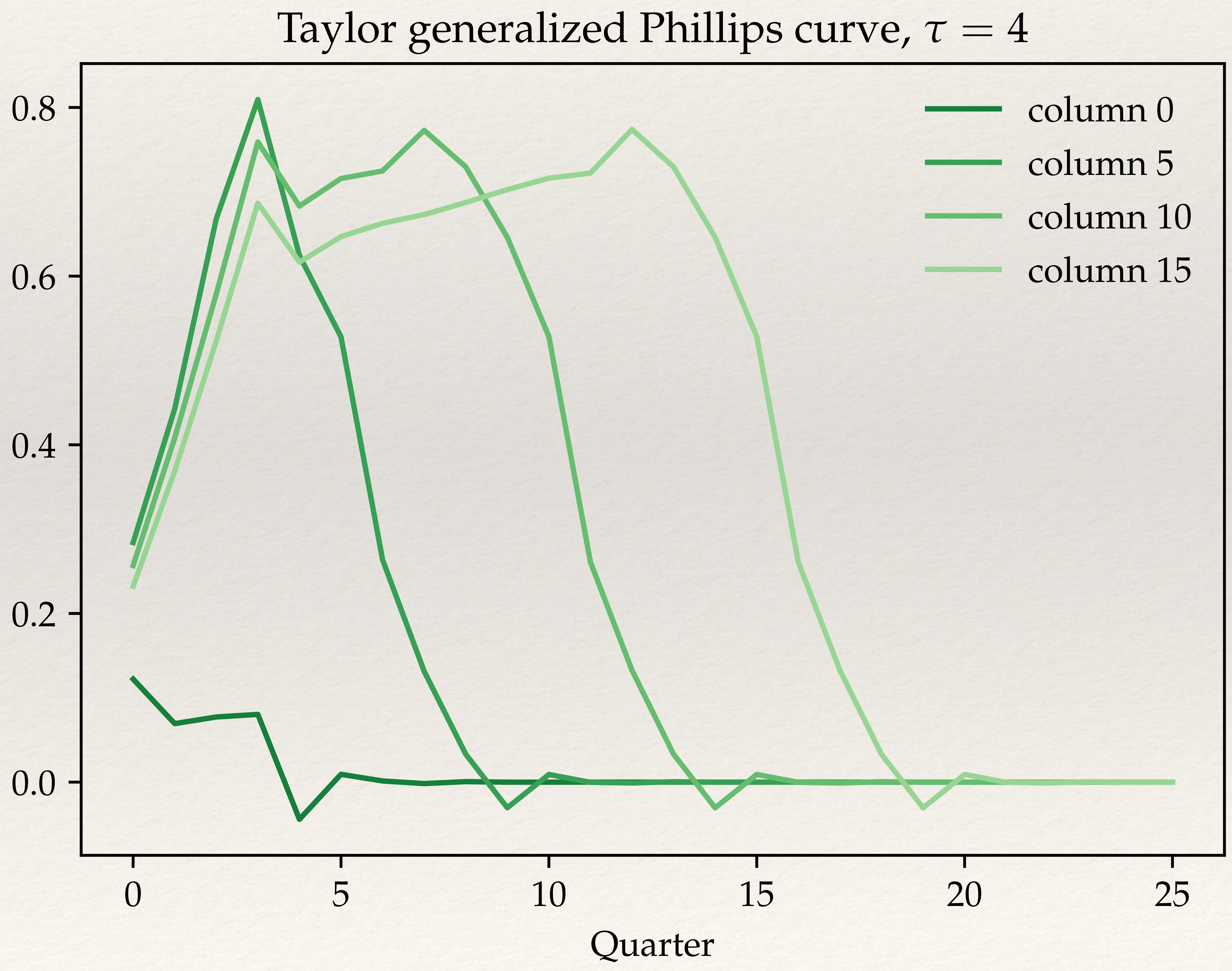
$\mathbf{K}$



Another time-dependent model: Taylor

- Taylor model: Get to reset every τ periods (e.g. every year). Survival: $1_{\{t \leq \tau\}}$





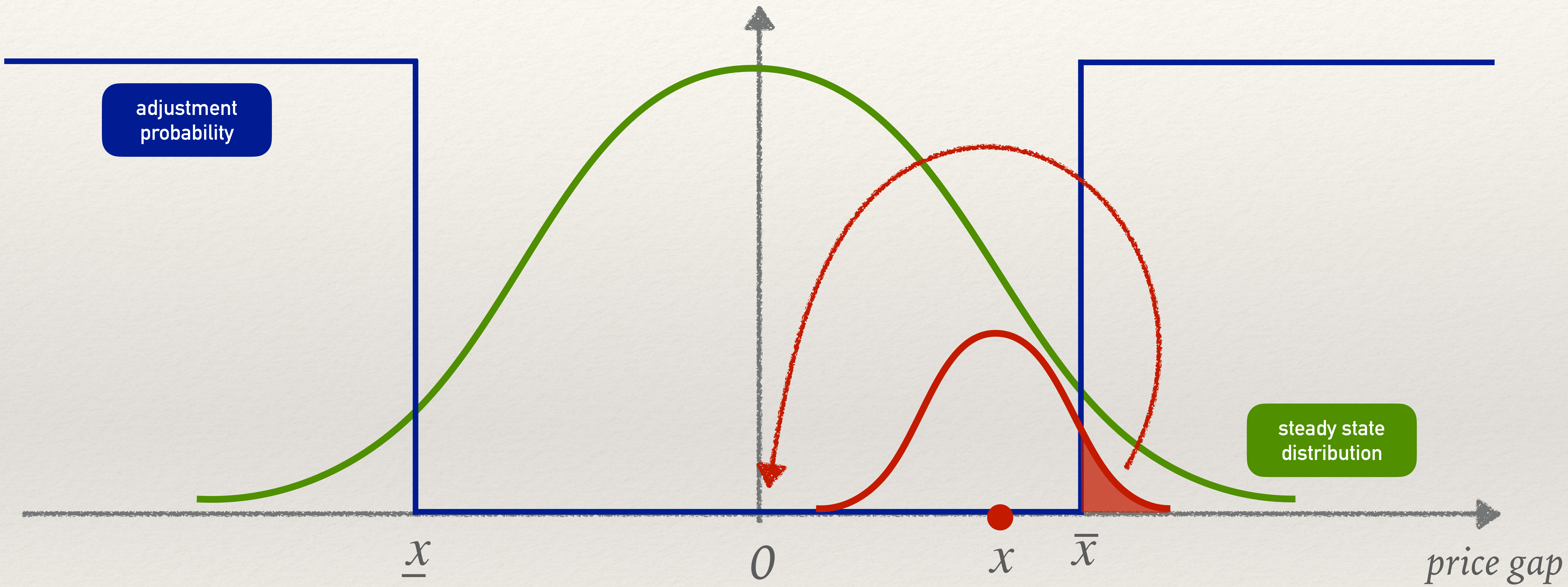
Menu cost model

- Mass 1 of firms, choosing distance to their optimal price (“**price gap**”) x_{it}
- Without any shocks, want to set $x_{it} = 0$! With shocks, want $x_{it} = \widehat{MC}_t$
- But each price reset is costs some $\xi > 0$ (“menu cost”)
- If price is not reset, price gap moves: $x_{it} = x_{it-1} + \epsilon_{it}$

$$\min_{\{x_{it}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{2} \left(x_{it} - \widehat{MC}_t \right)^2 + \xi 1_{\{x_{it} \neq x_{it-1} - \epsilon_{it}\}} \right]$$

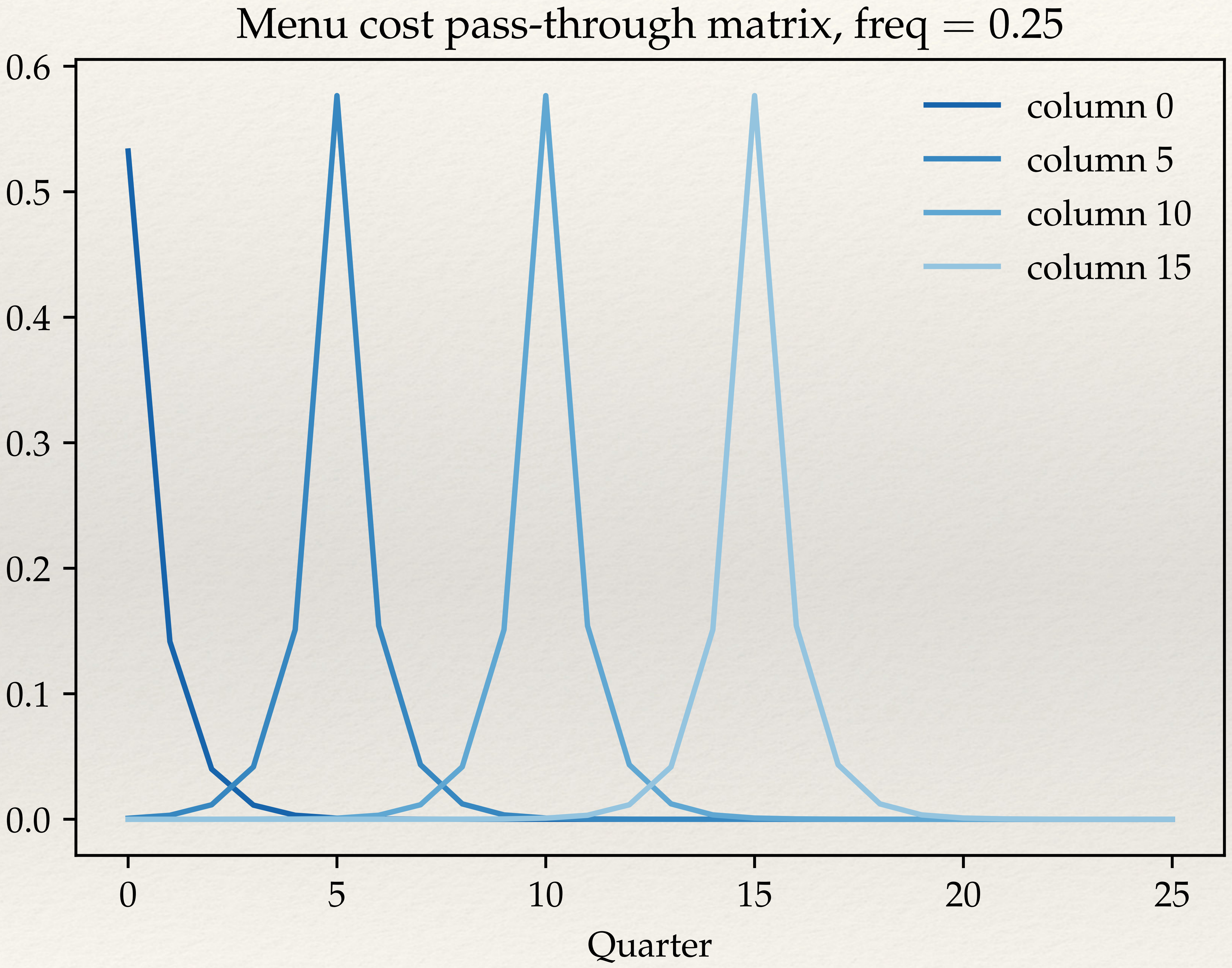
- Lots of evidence for this kind of behavior in micro data on price setting!

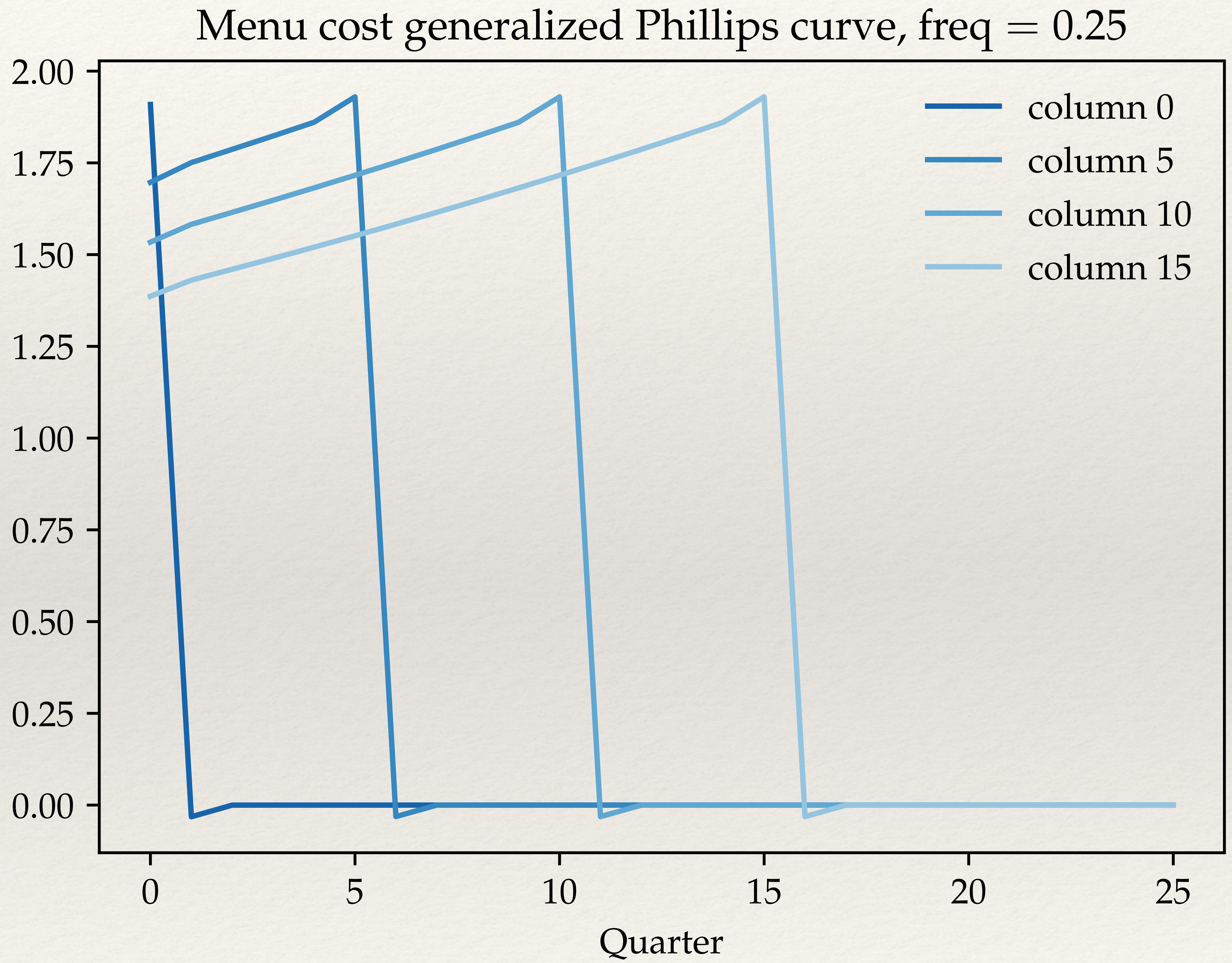
Mechanics of menu cost models



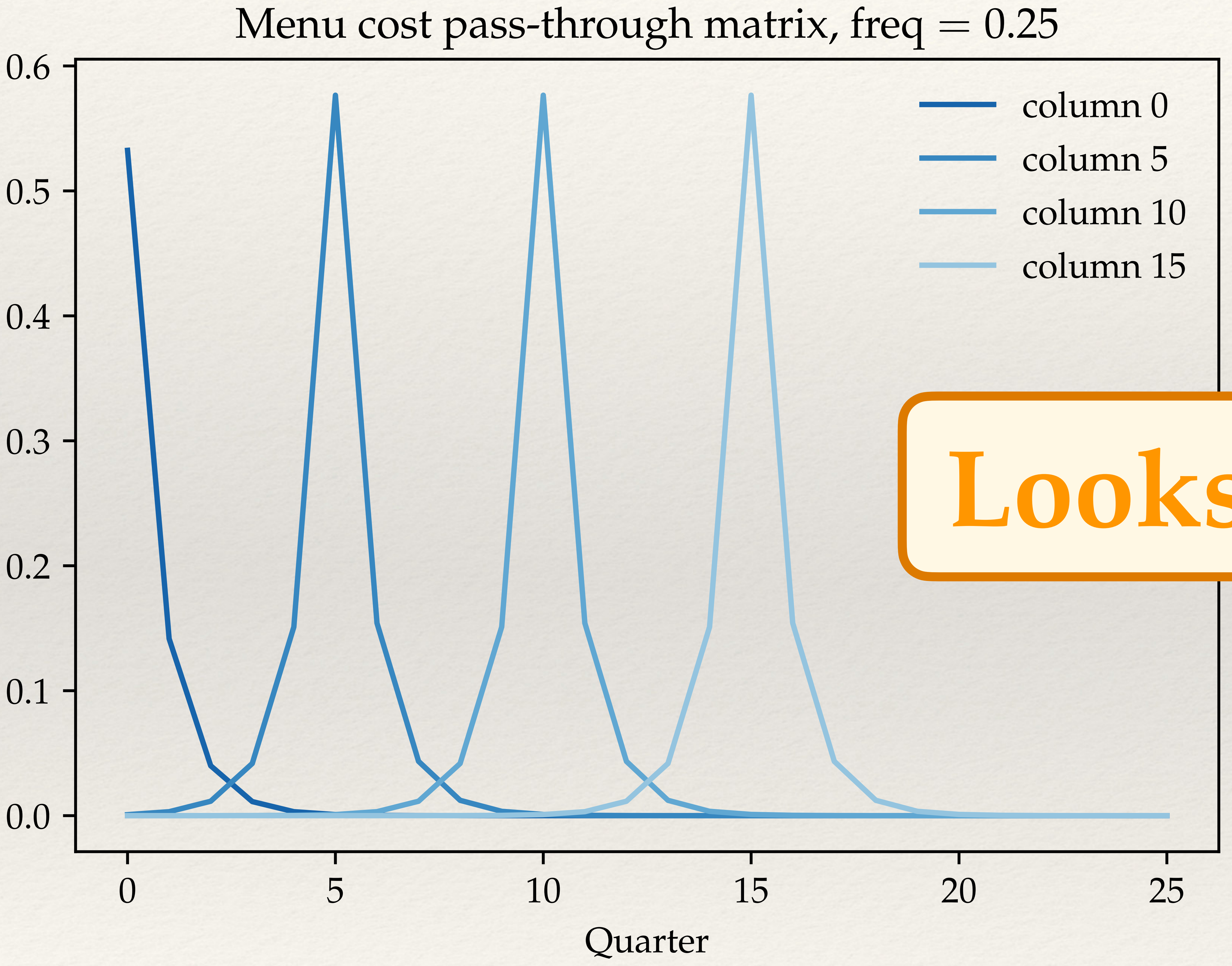
- Entire distribution of price gaps matters! "State dependent" model
- Hard to analyze… Main focus on permanent MC shocks, i.e. $\Psi \cdot \mathbf{1}$

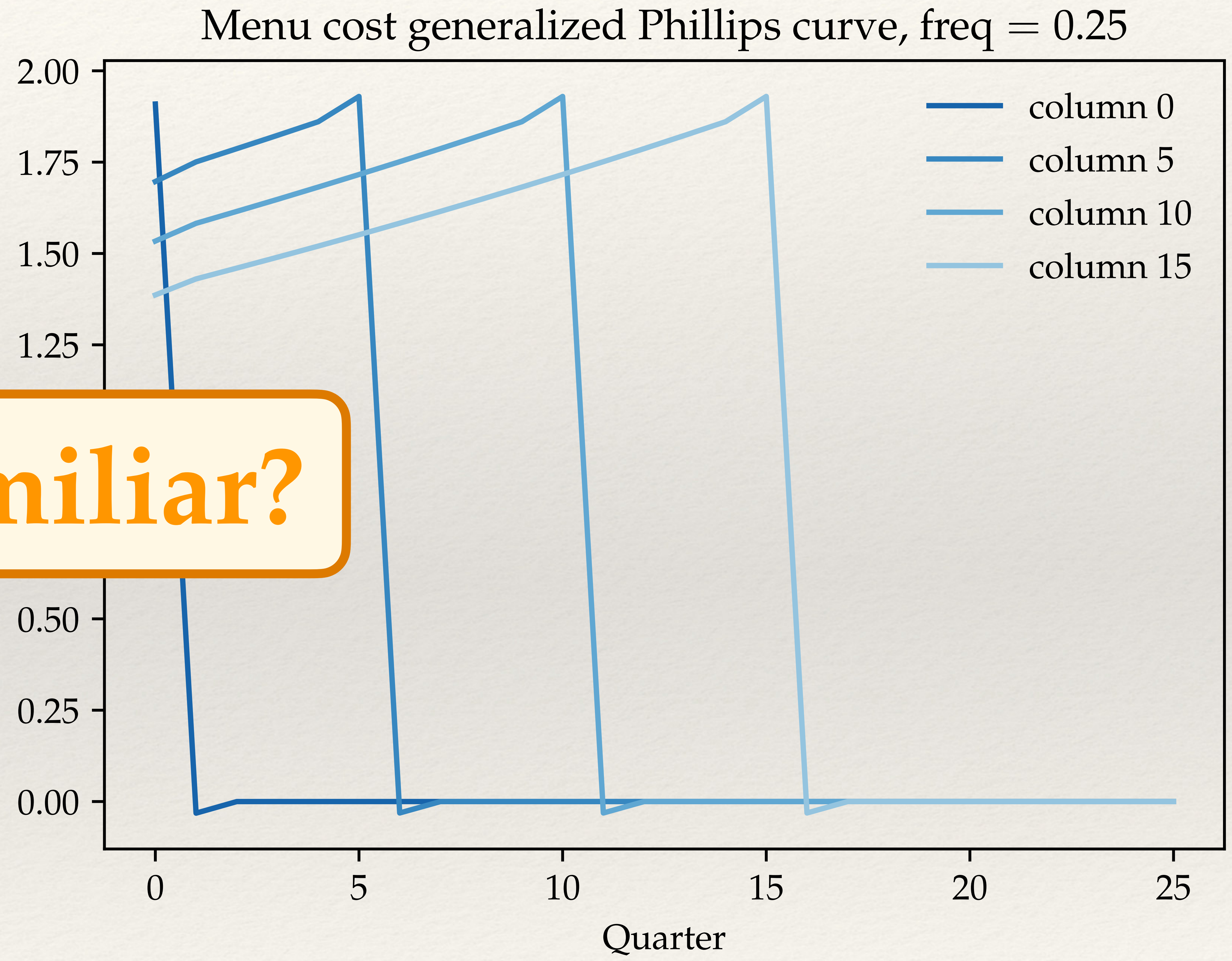
What do menu cost Jacobians look like?





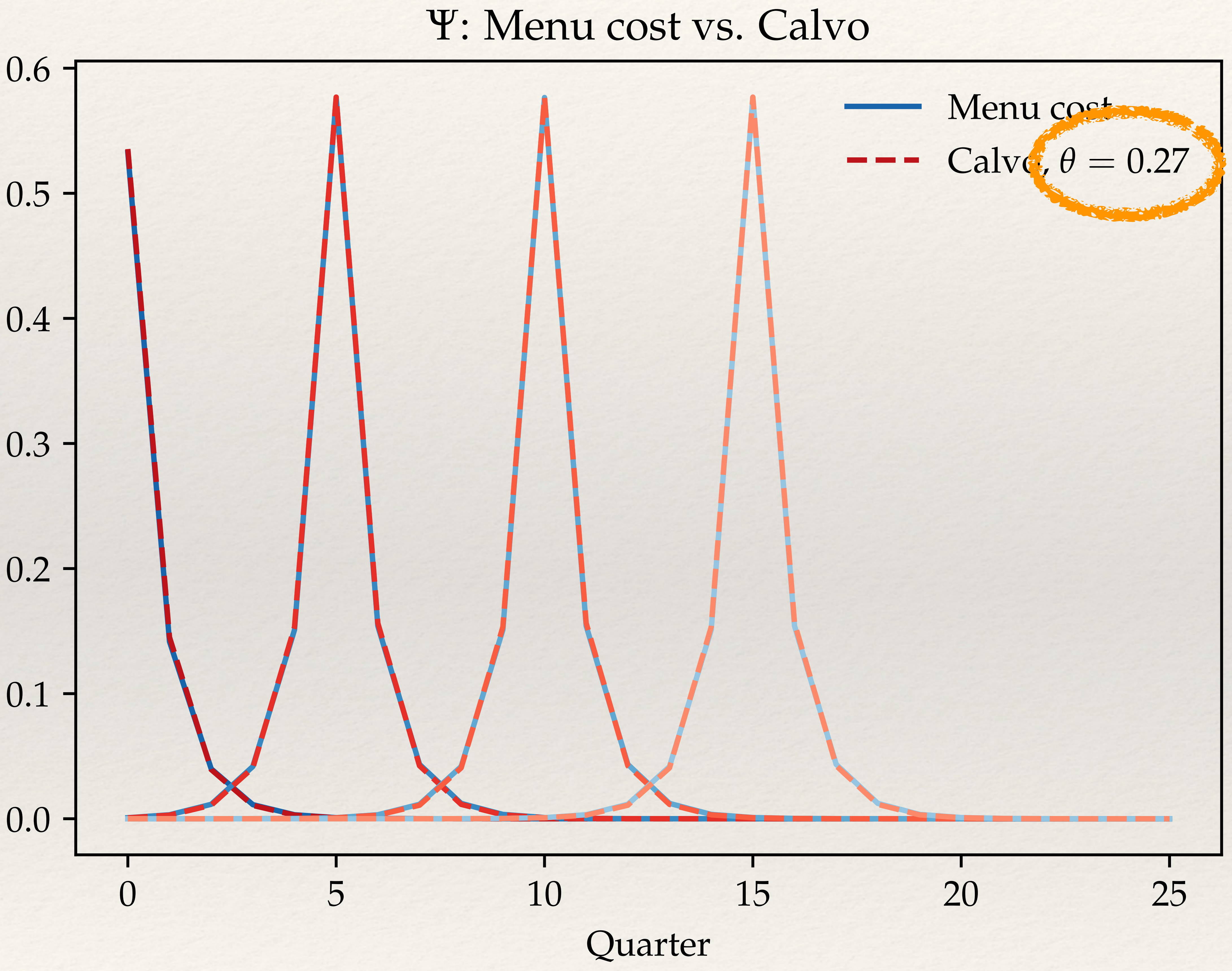
What do menu cost Jacobians look like?

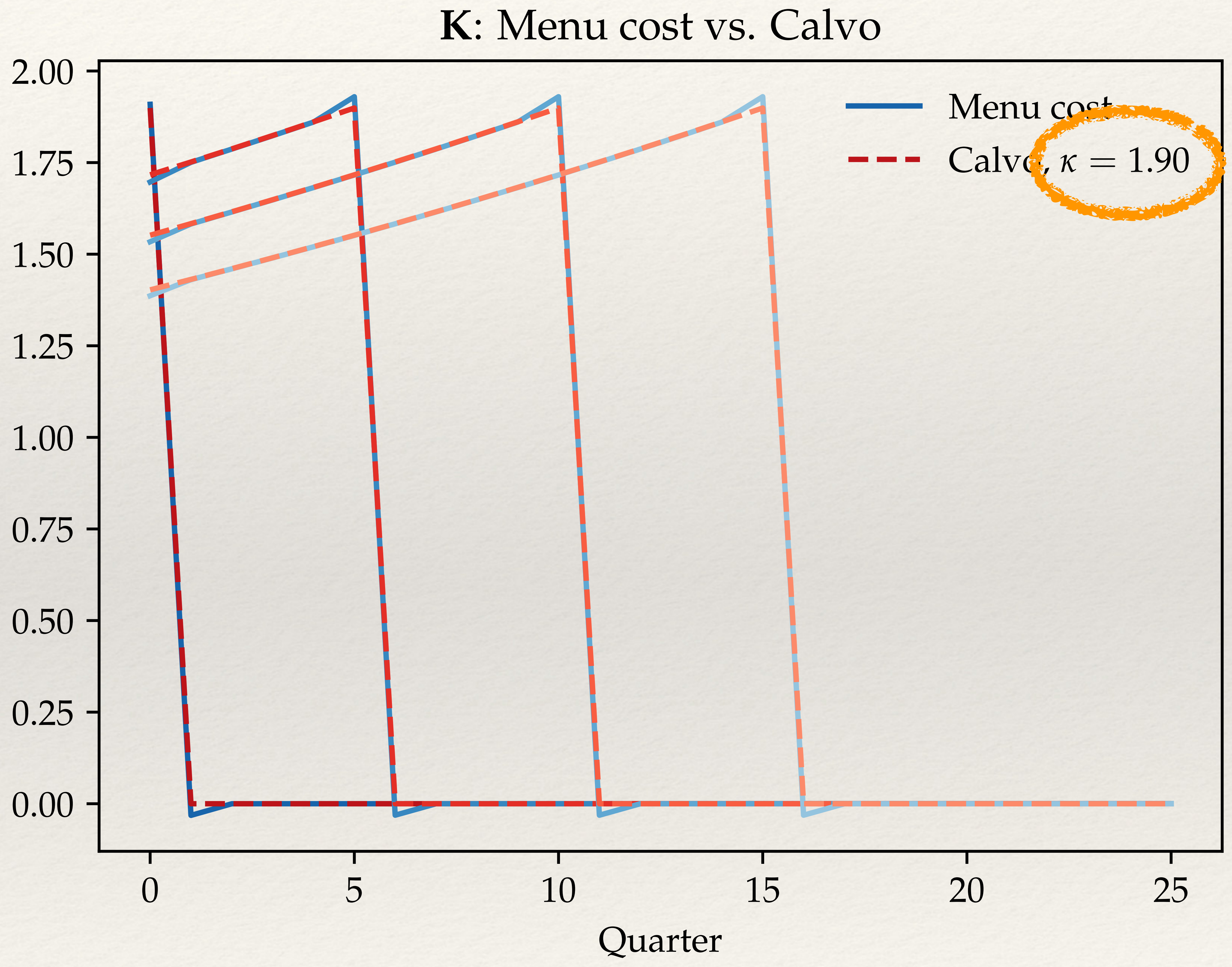




Looks familiar?

What do menu cost Jacobians look like?



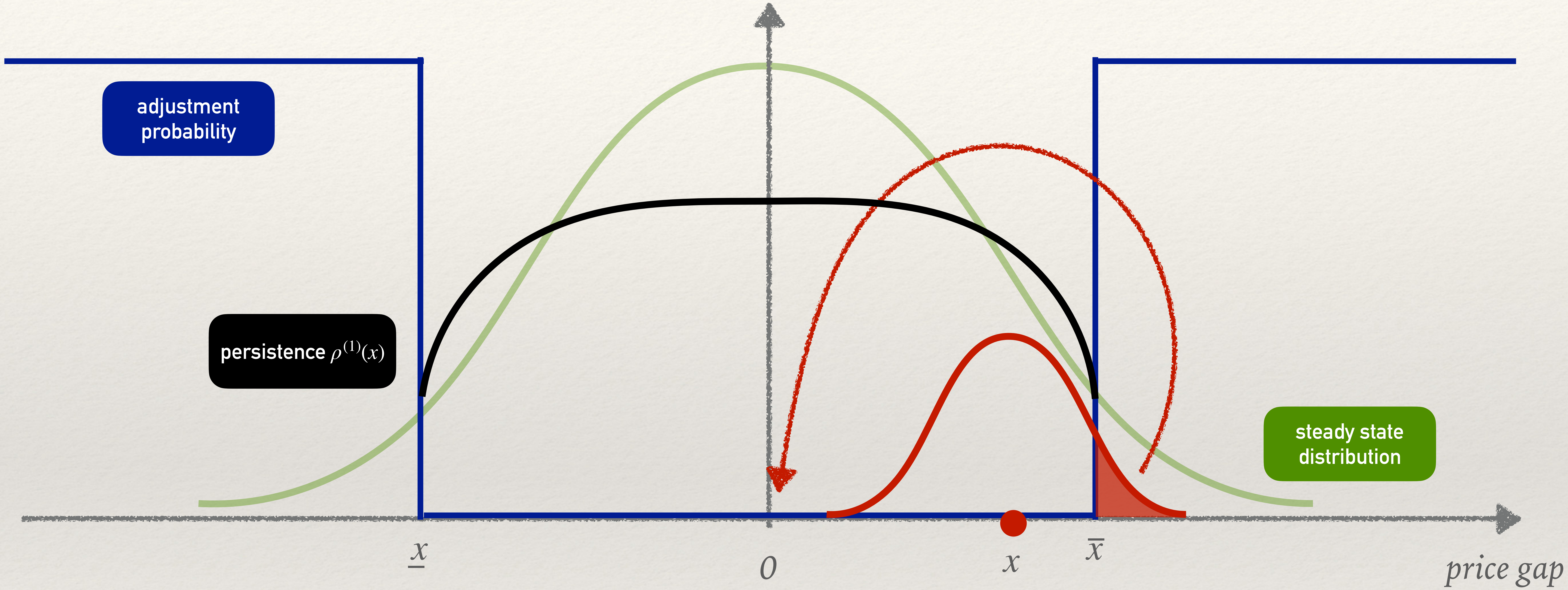


Numerical equivalence result

- **Pass through matrix** and **generalized Phillips curve** of menu cost models are well approximated by a Calvo model with a greater frequency of price resets.
- Since it holds for Jacobians, it holds for arbitrary menu cost shocks.
- This holds across various parameterizations of menu cost models
- To summarize:

Calvo	**Menu cost**
$\pi_t = \kappa \widehat{mc_t} + \beta \mathbb{E}_t \pi_{t+1}$	$\pi_t \approx \tilde{\kappa} \widehat{mc_t} + \beta \mathbb{E}_t \pi_{t+1}$ $\tilde{\kappa} > \kappa$

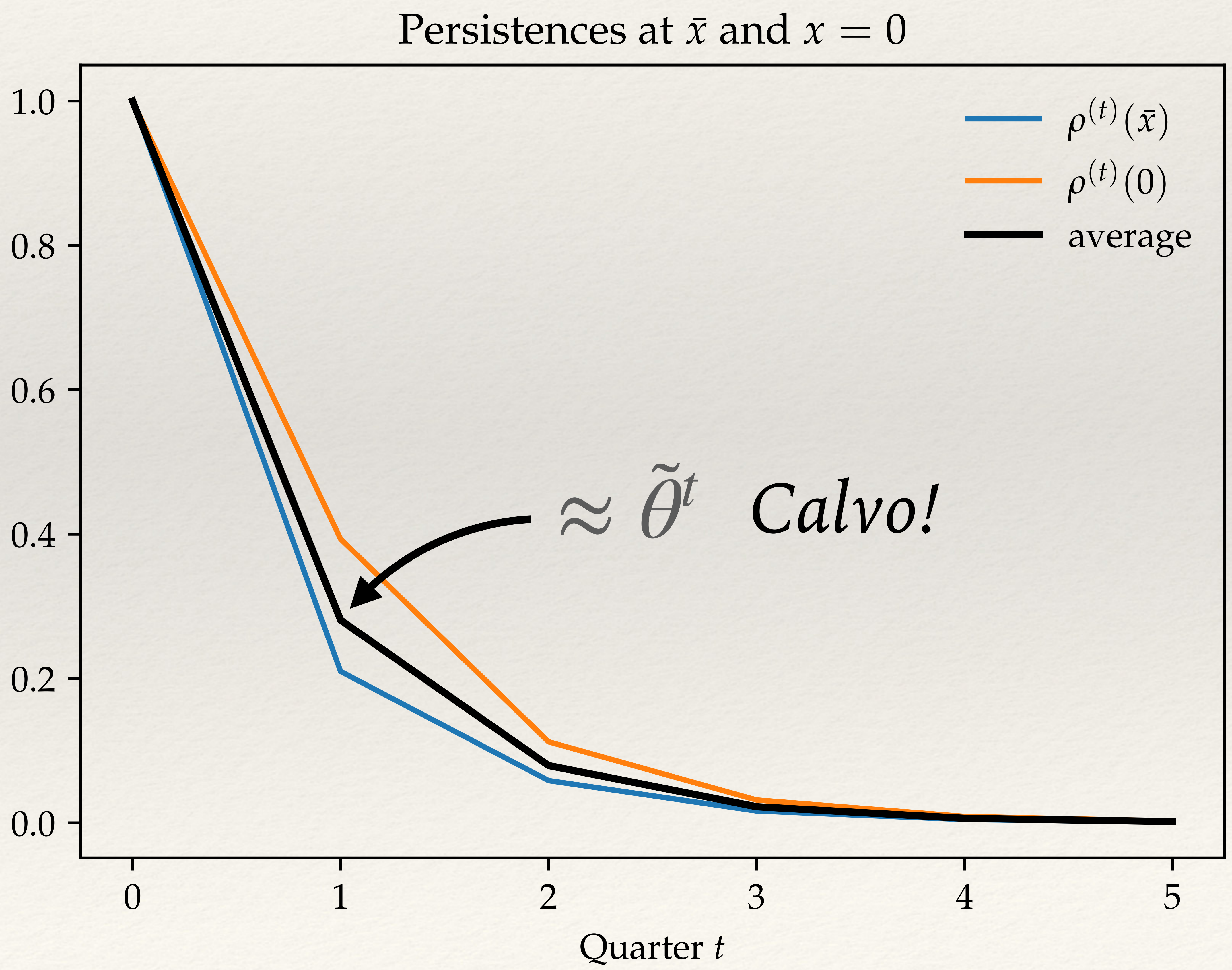
More mechanics of menu cost model



Define **persistence** of price gap x $\quad \rho^{(t)}(x) \equiv \dfrac{\mathbb{E}_0[x_t \,|\, x_0 = x]}{x} \quad \rho^{(t)}(0) \equiv \lim_{x \to 0} \rho^{(t)}(x)$

Exact equivalence result

- Menu cost model is **exactly the same** as mix of two time-dependent models
  - one with survival function equal to $\rho^t(0)$
  - one with survival function equal to $\rho^t(\bar{x})$
- Totally non-obvious!
- The two survival functions average to something close to exponential, ~ Calvo!



Takeaway

- Menu cost models are great in that they **match the micro data**!
- But they **fail at matching macro data**! (even worse than Calvo…)
  - still no inertia, too forward looking, slope κ too high
- How can we make progress? One idea: After lunch …