Difference-in-Differences with Spillovers: The Effect of Minimum Wage Increases on Prices in Other States

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Background

- Do minimum wage increases in one state affect outcomes of interest in other states?
- One literature tries to estimate the effect of minimum wage increases on store prices (Leung (2018), Ganapati and Weaver (2017), Renkin, Montialoux, and Sigenthaler (2017)) and employment (e.g. Card and Krueger (1994)).
  - This is amongst the most fundamental and most studied questions in economics.
- Yet, another literature documents that prices are often set uniformly across many stores in a chain (DellaVigna and Gentzkow (2019)).
- This implies a failure of the stable unit treatment value assumption (SUTVA).
  - Store prices in some states may depend on minimum wage changes in other states if stores are in chains that operate across multiple states.
  - Thus the “Control” group is also treated.
  - Notably, uniform pricing implies SUTVA failures for employment regressions as well – because prices cannot adjust, quantities must instead.
Introduction

- Today, we present our model of local and chain pricing.
  - With complicated treatments and spillovers across states, we want to guide our reduced-form empirical analysis with a model.
  - We are not (yet) estimating a structural model.
  - The model, we think, helps us assess the plausibility of parallel trends assumptions.
- Importantly, our model tells us how to define treatment in the presence of chain spillovers and provides us with estimating equations.
- We then present empirical results on the effects of minimum wage increases on prices in other states.
- Feedback at any point is welcome, but we would like to focus in particular on measuring chain-level pricing effects.
Outline

1. Data

2. Model

3. Empirical Results
Outline

Data

Model

Empirical Results
Data

- Nielsen Retail Scanner data provided by the Kilts Center at the University of Chicago.
- Weekly prices and quantities sold for about 35,000 stores and 4 million unique products (UPCs) from 2006 - 2017.
  - UPCs can be very specific: “Coca-Cola Classic, Canned, 6-Pack”.
- Scanner data covers more than half the total sales volume of US grocery and drug stores.
- Retail channels include food, drug, mass merchandise, convenience, and liquor.
- Also have panel data on state and federal minimum wages from the Department of Labor.
Uniform Pricing: “Coffee, Ground and Whole Bean”
Toothpaste, Paper Towels, Toilet Tissue, Bleach, and Candy

Weekly Price Levels in Chain 128, Graph 2 -- Module Dividers, Sorted by Zip

Stores, Organized by Module, Sorted Within by 3-Digit Zip Code

-10--.5  -5--.4  -4--.3  -3--.2
-.2--.15  -.15--.1  -.1--.05  -.05-0
0--.05  .05-.1  .1-.15  .15-.2
.2-.3  .3-.4  .4-.5  .5-10

2006  2007  2008  2009  2010  2011  2012
Uniform Pricing: Correlations

Pairwise Correlation of De-meaned Prices

- Chain 1 vs. Chain 2, N = 1796265
- Chain 1 vs. Chain 2, N = 4181200
Outline

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Empirical Results
Local Pricing

- Stores have constant returns to scale (CRS) production functions in minimum wage labor $L_i$, high skill labor $H_i$, and all other inputs $X_i$.

- Optimization yields a cost function:

$$ C_i(\overline{w}_s(i), w_i, r_i, Y_i) = \min_{L_i, H_i, X_i} \overline{w}_s(i)L_i + w_iH_i + r_iX_i \text{ s.t. } f_i(L_i, H_i, X_i) = Y_i, $$

where $\overline{w}_s(i)$ is the minimum wage in state $s(i)$, $w_i$ is the cost of high skill labor for store $i$, $r_i$ is the cost of all other inputs for store $i$, and $Y_i$ is store $i$'s output.

- It is a direct consequence of CRS and monopoly pricing that

$$ P_{i, local} = \mu_i C_i(\overline{w}_s(i), w_i, r_i, 1), $$

where $\mu_i \geq 1$ is the store’s markup over its constant marginal cost.

- Defining $\eta_k^i$ as the cost share of input $k$ for store $i$, this implies

$$ \frac{d \ln P_{i, local}}{d \ln \overline{w}_s(i)} = \frac{d \ln \mu_i}{d \ln \overline{w}_s(i)} + \eta_L^i + \eta_H^i \frac{d \ln w_i}{d \ln \overline{w}_s(i)} + \eta_X^i \frac{d \ln r_i}{d \ln \overline{w}_s(i)}. $$
Chain Pricing

- The cost function for a chain associated with store $i$, denoted $c(i)$, is

$$\sum_{i \in c(i)} C_i(\bar{w}_{s(i)}, w_i, r_i, Y_i) = \sum_{i \in c(i)} \bar{w}_{s(i)}L_i^* + w_iH_i^* + r_iX_i^*,$$

where asterisks denote stores’ conditional factor demands.

- Multiplying and dividing, we can define

$$C_{c(i)}(\bar{w}_{c(i)}, w_{c(i)}, r_{c(i)}, Y_{c(i)}) = L_{c(i)}^* \sum_{i \in c(i)} \bar{w}_{s(i)} \frac{L_i^*}{L_{c(i)}^*} + H_{c(i)}^* \sum_{i \in c(i)} w_i \frac{H_i^*}{H_{c(i)}^*} + X_{c(i)}^* \sum_{i \in c(i)} r_i \frac{X_i^*}{X_{c(i)}^*},$$

- For today, we will assume that the demand elasticity does not vary across stores within a chain.

  - This implies that the chain-level factor prices are fixed parameters in the monopolist’s profit-maximization problem.
  - Otherwise, the chain prices to shift business toward stores with more inelastic demand.
  - This is not a first-order effect, and is not what we want to focus on today.
Chain Pricing

So, the chain solves:

\[
P_{i}^{\text{chain}} = \arg \max_{P} \sum_{i \in c(i)} \left[ PY_i(P) - C_i(\bar{w}_s(i), w_i, r_i, Y_i(P)) \right] \\
= \arg \max_{P} PY_{c(i)}(P) - C_{c(i)}(\bar{w}_c(i), w_c(i), r_c(i), Y_c(i)(P)) \\
= \mu_{c(i)} C_{c(i)}(\bar{w}_c(i), w_c(i), r_c(i), 1)
\]

Analogously to our local pricing solution, we have

\[
\frac{d \ln P_{i}^{\text{chain}}}{d \ln \bar{w}_s(i)} = \frac{d \ln \mu_{c(i)}}{d \ln \bar{w}_s(i)} + \eta^c_L \frac{d \ln \bar{w}_c(i)}{d \ln \bar{w}_s(i)} + \eta^c_H \frac{d \ln w_c(i)}{d \ln \bar{w}_s(i)} + \eta^c_X \frac{d \ln r_c(i)}{d \ln \bar{w}_s(i)}
\]

where \(\eta^c_k\) is the cost share of input \(k\) for chain \(c(i)\).

Note that \(\frac{d \ln \bar{w}_c(i)}{d \ln \bar{w}_s(i)} = 1\) when a chain is only in one state.

For multi-state chains, the second term is muted relative to the local pricing case.
Simplifying Assumptions

- A variety of consumer setups lead to demand elasticities which do not depend on the minimum wage, leading us to set $d \ln \mu_i / d \ln w_s = 0$ for any $s$
  - The level of demand can still shift with minimum wage increases due to income effects
- We will also define $L_i$ and $H_i$ so that $H_i$ is labor high enough up in the wage distribution that it is unaffected by minimum wage increases (Autor et al. (2016), Cengiz et al. (2019), etc.)
  - Then $d \ln w_i / d \ln w_s = 0$ for any $s$
- Purely for today, to simplify notation, we will set
  - $d \ln r_i / d \ln w_s = d \ln r_{c(i)} / d \ln w_s$ for all $i \in c(i)$ and all $s$ (i.e., GE channel operates at chain level)
  - $\eta^i_X = \eta^{c(i)}_X$ for all $i \in c(i)$
The Combined Model

- We will use a difference specification later, so we don’t take a stance on the initial price levels.
- When changing store prices in response to a shock, the chain takes into account administrative and information costs captured in \( \chi_c(i)/(1 - \chi_c(i)) \), where \( \chi_c(i) \in [0, 1) \):

\[
\Delta P_i = \arg \min_{\delta} (\delta - \Delta P_i^{local})^2 + \frac{\chi_c(i)}{1 - \chi_c(i)} (\delta - \Delta P_i^{chain})^2
\]

\[
= \chi_c(i) \Delta P_i^{chain} + (1 - \chi_c(i)) \Delta P_i^{local}
\]
The Combined Model

Plugging in,

\[
\frac{d \ln P_i}{d \ln \bar{w}_{s(i)}} = \chi_c(i) \eta^c_L \frac{d \ln \bar{w}_c(i)}{d \ln \bar{w}_{s(i)}} + (1 - \chi_c(i)) \eta^i_L + \eta^c_X \frac{d \ln r_c(i)}{d \ln \bar{w}_{s(i)}} \quad \text{(Direct Effect)}
\]

and

\[
\frac{d \ln P_i}{d \ln \bar{w}_{s(i)'}} = \chi_c(i) \eta^c_L \frac{d \ln \bar{w}_c(i)}{d \ln \bar{w}_{s(i)'}'} + \eta^c_X \frac{d \ln r_c(i)}{d \ln \bar{w}_{s(i)'}'} \quad \text{(Out-of-State Effect)}
\]

If \( \chi_c(i) = 0 \) (i.e., completely local pricing), then

\[
\frac{d \ln P_i}{d \ln \bar{w}_{s(i)}} - \frac{d \ln P_j}{d \ln \bar{w}_{s(i)}} = \eta^i_L, \quad i, j \in c, \ s(i) \neq s(j)
\]

If \( \chi_c(i) \to 1 \) (i.e., completely chain-level pricing), then

\[
\frac{d \ln P_i}{d \ln \bar{w}_{s(i)}} - \frac{d \ln P_j}{d \ln \bar{w}_{s(i)}} = 0, \quad i, j \in c, \ s(i) \neq s(j)
\]
In the data, many minimum wages may change in a given period, and there will be many other shocks $Z_i$ that affect store $i$.

WLOG, we can model the price as $P_i(\overline{w}_s(i), \overline{w}_{-s}(i), Z_i)$.

Taking a total differential, using the notation $\Delta k = d \ln k$, we have:

$$\Delta P_i = \sum_s \frac{\partial \ln P_i}{\partial \ln \overline{w}_s} \Delta \overline{w}_s + \epsilon_i,$$

where $\epsilon_i$ is the response due to other shocks $Z_i$.

Plugging in the solutions from our model, we get

$$\Delta P_i = (1 - \chi_{c(i)}) \eta_L^i \Delta \overline{w}_s(i) + \chi_{c(i)} \eta_L^c(i) \Delta \overline{w}_c(i) + \eta_X^c(i) \Delta r_c(i) + \epsilon_i,$$

This is exact for infinitesimal changes but a first-order approximation for large changes.

An issue is we do not observe $\Delta r_c(i)$ in the data.
Outline

Data

Model

Empirical Results
Recall our solution

\[ \Delta P_i = (1 - \chi_c(i)) \eta_L \Delta \bar{w}_{s(i)} + \chi_c(i) \eta_L \Delta \bar{w}_c(i) + \eta_X \Delta r_c(i) + \epsilon_i \]

Because \( \Delta \bar{w}_c(i) \) is a change in a weighted average of minimum wages, where the average is over states in which the chain operates, this motivates the regression

\[ \Delta P_{i,c,s,t} = \theta_{s,t} + \gamma_{c,s} + \sum_{s' \neq s} \beta_{c,s'} \Delta \bar{w}_{s',t} 1 \{ c \in s' | t \} + \epsilon_{i,c,s,t}, \]

This utilizes a fixed-effects identification strategy: conditional on state-time and chain-state fixed effects, minimum wage increases in other states are assumed to be uncorrelated with unobserved determinants of price increases in the own state.

> Cluster standard errors at the chain level.

If we are identified and the model is correctly specified,

\[ \beta_{c,s'} = \chi_c \eta_L \frac{d \ln \bar{w}_c}{d \ln \bar{w}_{s'}} + \eta_X \frac{d \ln r_c}{d \ln \bar{w}_{s'}} \]
Chain Effect - Texas Minimum Wage Increase

Log Point Increase in State Price Levels due to Chain Pricing
Due only to a 1 log point minimum wage increase in TX
(only effects significant at the 99% level)
Chain Effect - Kansas Minimum Wage Increase

Log Point Increase in State Price Levels due to Chain Pricing
Due only to a 1 log point minimum wage increase in KS
(only effects significant at the 99% level)
Log Point Increase in State Price Levels due to Chain Pricing

Due only to a 1 log point minimum wage increase in FL
(only effects significant at the 99% level)
Direct Effect, Within-Chain Variation

- As mentioned, some research on the effects of minimum wage changes uses within-chain identification.
- One of the implications of our model was that this should result in null effects.
- We can run

\[ \Delta P_{r,t} = \alpha_{c(r),t} + \sum_{j=-K}^{K} \tau_j \Delta \bar{w}_{s(r),t+j} + \epsilon_{r,t}, \]

where \( \alpha_{c(r),t} \) are chain-by-time fixed effects, to look at within-chain effects of own-state price increases.
Direct Effect, Within-Chain Variation

Here, estimate $\tau_j \approx 0$ for all $j$. 

Cross-Chain Estimates
Conclusion

- We observe that the empirical fact that most chains price uniformly across stores has implications for the literature on the effects of minimum wage increases.
  - SUTVA violated, control group also (partially) treated

- We set up a model of local- and chain-level pricing – and the chain’s decision between the two – which illustrates these points and guides our empirical analysis.

- We find evidence of strong and significant effects of state minimum wage increases on other states’ prices
  - We also show that, as our model predicts, within-chain identification leads to estimation of null effects.

- We are working on obtaining the data necessary to extend our analysis to employment/wage effects of minimum wage increases.

- We think that chain structures are likely to have important consequences yielding SUTVA violations in other literatures as well (e.g., cross-sectional fiscal multipliers, sales/excise/property taxes, etc.).
A 10% increase in the minimum wage leads to a 1.0% increase in prices ($t = 3.9$)

Previous estimates, not controlling for spillovers, range from 0% to 0.8%