Frontier Topics in Empirical Economics: Week 7
Bartik Instruments

Zibin Huang [1]

[1] College of Business, Shanghai University of Finance and Economics

November 7, 2025

Introduction

- We have already learned some basic IV methods and their extensions
- Today we will investigate a particular type of IV
- Bartik instrument, or shift-share instrument (SSIV)
- It is widely used in different contexts
- Especially trade and migration (spatial economics)
- How should we use it? What is its regression assumption?

Introduction

- We will introduce two different frameworks of this instrument
  - Goldsmith-Pinkham, Sorkin, and Swift (2020) consider share as IV, shift as weight
  - Borusyak, Hull, and Jaravel (2022) consider shift as IV, share as weight
- You can validate your regression by proving either set of assumptions are correct
- It depends on your context

Motivating Example: Card (2009)

- Let's start with an example from Card (2009)
- What is the impact of immigrant ratio on native-immigrant wage gap?

$$y_l = \beta_0 + \beta ln x_l + \beta_2 C_l + \epsilon_l \tag{1}$$

- l is location, y is log wage gap between immigrants and natives, x is ratio of immigrant labor to native labor, C is location-level control
- x is endogenous: Some positive productivity local shock affects both x and y

Motivating Example: Card (2009)

- Let's use an IV for x
- We have data for 1980,1990, and 2000
- We construct a shift-share IV B_l as follows:

$$B_l = \sum_k \underbrace{Z_{lk,1980}}_{share} \cdot \underbrace{g_k}_{shift} \tag{2}$$

$$Z_{lk,1980} = (N_{lk,1980}/N_{k,1980}) \times (1/P_{l,2000}) \tag{3}$$

- k is home country, $N_{lk,1980}$ is the number of immigrants in l from k in 1980, $P_{l,2000}$ is population in l in 2000
- $Z_{lk,1980}$ evaluates the base year share of immigrants from k in l
- g_k is the number of people arriving the US from 1990 to 2000 from k

Motivating Example: Card (2009)

- What is the basic idea of this IV?
  - (1) Relevance: Clustering of immigrants from the same country (Chinese in SF)
  - (2) Exclusion: The local exposure of the national shock is not related to other local shocks
- It decomposes local immigrant into local-origin country
- This is an instrument with "Local Share" $\times$ "National Growth (Shift)"
- We call this shift-share/Bartik instrument

Motivating Example: Autor, Dorn, and Hanson (2013)

- Another important example is Autor, Dorn, and Hanson (2013) on China shock
- What is the impact of China's import on local labor market in the U.S.?
- They construct a shift-share variable as follows:

$$\Delta IPW_{it} = \sum_j \frac{L_{ijt}}{L_{jt} \cdot L_{it}} \Delta M_{jt}$$

- i is region, j is industry, t is year
- L_{ijt} is employment in region i industry j
- L_{jt} is total employment in industry j in the U.S.
- L_{it} is total employment in region i
- ΔM_{jt} is import growth from China to the U.S. in industry j

Goldsmith-Pinkham, Sorkin, and Swift (2020): Share as IV

- How to interpret this shift-share IV?
- Let's first investigate Goldsmith-Pinkham, Sorkin, and Swift (2020)
- In this paper, we consider share as IV, shift as weight

Goldsmith-Pinkham, Sorkin, and Swift (2020): Definition of Bartik IV

- Let's define Bartik IV generally
- We have the following equation

$$y_{lt} = D_{lt}^{\prime}\rho + x_{lt}\beta_0 + \epsilon_{lt} \tag{4}$$

- l is location; t is time; D are controls; β_0 is parameter of interest
- x_{lt} is some (employment) growth rate
- y_{lt} is some (wage) outcome growth rate
- x and y can also be level variables when location FE is controlled
- We assume that $x_{lt} \not\perp \epsilon_{lt}$, need an IV
- Bartik IV comes from two identities

Goldsmith-Pinkham, Sorkin, and Swift (2020): Definition of Bartik IV

- Identity 1: Decompose Location-level growth variable to location-industry-level variable and its growth
- Usually location-industry level, or in Card (2009), location-origin country level

$$x_{lt} = Z_{lt} G_{lt} = \sum_{k=1}^{K} z_{lkt} g_{lkt}$$

  z_{lkt} is the location-industry share at t, g_{lkt} is the location-industry growth at t
- Identity 2: Decompose location-industry growth into national and local components

$$g_{lkt} = g_{kt} + \tilde{g}_{lkt}$$

  g_{kt} is the national industry growth, $\tilde{g}_{lkt}$ is the location-industry growth shock

Goldsmith-Pinkham, Sorkin, and Swift (2020): Definition of Bartik IV

- Assume that we have a baseline period 0
- We construct Bartik IV B_{lt} as:

$$B_{lt} = Z_{l0} G_t = \sum_k \underbrace{z_{lk0}}_{Share} \underbrace{g_{kt}}_{Shift} \tag{5}$$

- The first part is the initial share of industry k in location l
- The second part is the national growth of industry k
- Fix z at 0 and drop $\tilde{g}_{lkt}$ from the identity $\Rightarrow$ Bartik IV
- Before we formally establish the equivalence between Bartik IV and GMM
- Let's consider two special cases

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Case 1: Two industries and One period
- Shares sum to 1: $z_{l2} = 1 - z_{l1}$

$$B_l = z_{l1}g_1 + z_{l2}g_2 = g_2 + (g_1 - g_2)z_{l1}$$

- We have the first stage:

$$x_l = \gamma_0 + \gamma B_l + \eta_l = \underbrace{(\gamma_0 + \gamma g_2)}_{constant} + \underbrace{\gamma(g_1 - g_2)}_{coefficient} z_{l1} + \eta_l$$

- Using Bartik in 2SLS is identical to using single IV, z_{l1}

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Case 2: Two industries and Two periods

$$B_{lt} = g_{1t} z_{l10} + g_{2t} z_{l20} = g_{2t} + (g_{1t} - g_{2t}) z_{l10}$$

- Assume that we control for time FE, we have a first stage:

$$x_{lt} = \tau_t + \gamma B_{lt} + \eta_{lt} = \underbrace{(\tau_t + g_{2t}\gamma)}_{\tilde{\tau}_t} + z_{l10}(g_{1t} - g_{2t})\gamma + \eta_{lt}$$

- Now we cannot directly say only z_{l10} is the instrument
- Because with two periods, $g_{1t} - g_{2t}$ is not a constant
- Let's further decompose the equation

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Denote indicator function as $\mathbf{1}(\cdot)$, we have:

$$g_{1t} - g_{2t} = \mathbf{1}(t = 1)(g_{11} - g_{21}) + \mathbf{1}(t = 2)(g_{12} - g_{22})$$

- Then first stage becomes:

$$x_{lt} = \tilde{\tau}_t + z_{l10}\mathbf{1}(t = 1) \underbrace{(g_{11} - g_{21})\gamma}_{\text{rescaled parameter}\tilde{\gamma}_1} + z_{l10}\mathbf{1}(t = 2) \underbrace{(g_{12} - g_{22})\gamma}_{\text{rescaled parameter}\tilde{\gamma}_2}$$

- This is running x on the time FE and two interactions of z_{l10} and time dummies
- $g_{12} - g_{22}$ is the relative industry growth rate (shock)
- What is the underlying research design here?

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Growth rate: policy effect size;
- Initial share: Exposure to some policy
- Whether locations with more industry 1, experience different changes in x following shocks whose effect depends on industry sizes
- More clear if we consider period 1 as some pre-period
- Then we can set $g_{11} - g_{21} = 0$: Before policy/after policy
- DID specification! $\tilde{\gamma}_1 = 0 \Rightarrow$ parallel pre-trend

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Assume that we have K industries and one period, stack all variables to matrix
- Let $M_D = I - D(D'D)^{-1}D'$ be the annihilator matrix, $X^{\perp} = M_D X$
- Z is share and G is shock

Proposition 1 in PSS(2020)

We define Bartik and GMM esimator using industry shares as instruments:

$$\hat{\beta}_{Bartik} = \frac{B'Y^{\perp}}{B'X^{\perp}}, \hat{\beta}_{GMM} = \frac{X^{\perp'}ZWZ'Y^{\perp}}{X^{\perp'}ZWZ'X^{\perp}}$$

If $W = GG'$, then $\hat{\beta}_{Bartik} = \hat{\beta}_{GMM}$

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Bartik IV is equivalent to GMM estimator with local industry shares as instruments and national growth rate variance as weights
- Combined just-identified IV vs. Multiple over-identified IV
- The results can be extended to K industries and T periods case

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

- Asymptotic in location dimension: $L \rightarrow \infty$, with fixed T, K
- Asymptotic in other dimensions (and different research designs) are discussed in the next paper
- Assumption 1: Relevance
- Assumption 2 (Strict Exogeneity): $E[\epsilon_{lt} z_{lk0} | D_{lt}] = 0, \forall\, k$ with $g_k \neq 0$

Proposition 2 in PSS(2020)

Given assumption 1 and 2,

$$plim \hat{\beta}_{Bartik} - \beta_0 = 0$$

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

Generally, when is Assumption 2 plausible?

- Initial industry share is mean independent of unobserved outcome levels
  Wrong!
- Initial industry share is mean independent of unobserved outcome changes
  Plausible
- Keep in mind, when using Bartik IV
  Either control for location+time FE, or use growth variable as y!

Goldsmith-Pinkham, Sorkin, and Swift (2020): Bartik IV and GMM

When is Assumption 2 plausible?

- This is an "exposure design" (similar to DID)
- Different exposures of locations to national industry-level shocks affect outcomes only through changing x
- There is no systematic difference in terms of unobserved local shocks for places with different exposures (parallel trend)
- Think of Shanghai, Hong Kong and Shenyang, Wuhan
  - SH, HK are more involved in finance industry than SY, WH
  - If a financial crisis happens, SH, HK are more exposed
  - We have to assume that there is no other unobserved shocks hitting SH, HK and SY, WH differently
  - The trend of economic situations (without crisis shock) should be parallel

Goldsmith-Pinkham, Sorkin, and Swift (2020): Decompose Bartik IV

- Bartik IV is a combination of many industries (Black box)
- Which industry is driving the results?

Goldsmith-Pinkham, Sorkin, and Swift (2020): Decompose Bartik IV

- We can decompose it into a combination of just-identified estimates on each instrument (for each industry)

Proposition 3 in PSS(2020)

We can write

$$\hat{\beta}_{Bartik} = \sum_k \hat{\alpha}_k \hat{\beta}_k$$

where

$$\hat{\beta}_k = (Z_k' X^{\perp})^{-1} Z_k' Y^{\perp}, \hat{\alpha}_k = \frac{g_k Z_k' X^{\perp}}{\sum_{k'} g_{k'} Z_{k'}' X^{\perp}}$$

Goldsmith-Pinkham, Sorkin, and Swift (2020): Decompose Bartik IV

- We construct a single instrument for each industry $B_k = z_{lk0} g_k$
- $\hat{\beta}_k$ is IV estimator for each instrument k
- $\hat{\alpha}_k$ is called Rotemberg weight
- The Rotemberg weight means how important this single industry is
- If $\hat{\alpha}_k$ is large, misspecification on this industry is dangerous
- If $\hat{\alpha}_k$ is small, misspecification on this industry could be fine
- In practice, report industries with the highest weights

Goldsmith-Pinkham, Sorkin, and Swift (2020): Decompose Bartik IV

Tips

- This decomposition is different from the main GMM interpretation
- Bartik IV and GMM equivalence is discussed in a joint estimation context
- Bartik IV is equivalent to a joint GMM with shares as IVs (in one regression)
- Bartik IV decomposition means Bartik IV can be decomposed to a combination of K separately estimated IV estimators
- We run these IV regs one by one (for each industry share), then take weighted average of each regression coefficient $\hat{\beta}_k$

Goldsmith-Pinkham, Sorkin, and Swift (2020): Heterogeneous TE

- In a restricted heterogeneous effect case: Bartik IV is a combination of location level treatment effect
- Weights can be negative: lead the estimator to be uninterpretable
- For single industry share IV:
  We need an assumption similar to monotonicity in Imbens and Angrist (1994)
- For combined Bartik IV:
  Monotonicity for each single instrument is not enough
- In general, Bartik IV does not have a LATE interpretation

Goldsmith-Pinkham, Sorkin, and Swift (2020): Heterogeneous TE

- You will find similar things in the forthcoming lectures when we discuss complicated DID designs
- When treatment effect patterns become more and more complicated
- For instance dynamic, heterogeneous...
- You can hardly identify meaningful causal parameters using simple regressions
- Is this just coincidence?
- No. This is an intrinsically problem. Think about why

Goldsmith-Pinkham, Sorkin, and Swift (2020): Empirical Suggestions

- Now we have introduced an econometrics analysis of the Bartik IV
- What should we do in our empirical research if we want to interpret Bartik IV in the framework of Goldsmith-Pinkham, Sorkin, and Swift (2020)?
- First, remember, always add in location and time FE
- Second, focus on industries with high Rotemberg weights

Goldsmith-Pinkham, Sorkin, and Swift (2020): Empirical Suggestions

Some tests you can implement

- Test 1: Correlations of controls and industry compositions
- Assume that there are some covariates predicting changes in y not through x
- Test whether these location covariates are correlated with the industry shares
- Since industry shares need to affect y only through changes in x
- This is a balance test
- Example: y is employment; x is wage; z is manufacturing share; covariate d is immigrant share
- A suggestion from GSS: control for higher level shares

Goldsmith-Pinkham, Sorkin, and Swift (2020): Empirical Suggestions

- Test 2: Test for pre-trends if you have pre-shock period
- In specification with pre-period, you are doing DID
- Initial shares are local policy exposure; Growth rates are policy size
- Check pre-trends for both overall Bartik IV and single industry IV with high weight
- Whether locations with high shares of a main industry is different to locations with low shares in trends

Goldsmith-Pinkham, Sorkin, and Swift (2020): Empirical Suggestions

- Test 3: Overidentification Tests
- The main equivalence result tells us Bartik IV is an over-identified GMM
- Let's run overidentification test to check the validity of the bundle of share instruments
- If it is rejected, there are two possibilities
- Either your instruments are not exogenous (misspecification)
- Or there is heterogeneous treatment effect etc...
- This is not so recommended

Borusyak, Hull, and Jaravel (2022): Shift as IV

- We have already investigated Goldsmith-Pinkham, Sorkin, and Swift (2020)
- They interpret the share part as IV and the shift part as weight
- Another framework is proposed by Borusyak, Hull, and Jaravel (2022)
- In contrast, they interpret the shift part as IV and the share part as weight
- The identification assumption then becomes the "random assignment of shocks"

Borusyak, Hull, and Jaravel (2022): Settings

- Assume that we have the following shift-share IV:

$$z_l = \sum_k s_{lk} g_k, \quad k = 1, 2, ..., K$$

- s_{lk} is the share of industry k in location l
- g_k is the national shift for industry k
- We seek to estimate parameter β in the following regression:

$$y_l = \beta x_l + w_l^{'} \gamma + \epsilon_l$$

- w is the set of controls
- A valid instrument satisfies moment condition: $E[\sum_l z_l \epsilon_l] = 0$

Borusyak, Hull, and Jaravel (2022): Shock-level Equivalence

- Now we derive the equivalence between the original regression and a shock-level regression
- Plug the definition of SSIV into the moment condition:

$$E[\sum_{l} z_l \epsilon_l] = E[\sum_{l} \sum_{k} s_{lk} g_k \epsilon_l]$$

Borusyak, Hull, and Jaravel (2022): Shock-level Equivalence

- We exchange the order of the summation and have:

$$E[\sum_l z_l \epsilon_l] = E[\sum_k \sum_l s_{lk} g_k \epsilon_l] = E[\sum_k g_k \sum_l s_{lk} \epsilon_l]$$

$$= E[\sum_k g_k (\frac{\sum_l s_{lk}\epsilon_l \cdot \sum_l s_{lk}}{\sum_l s_{lk}})] = E[\sum_k s_k g_k \bar{\epsilon}_k]$$

- $s_k = \sum_l s_{lk}$ is the sum of shares of industry k for all locations
- $s_k = 1$ in many common examples
- $\bar{\epsilon}_k = \frac{\sum_l s_{lk}\epsilon_l}{\sum_l s_{lk}}$ is a weighted average of unobserved terms
- It transforms the original ϵ from location-level l to industry-level k

Borusyak, Hull, and Jaravel (2022): Shock-level Equivalence

- Therefore, it transforms the identification assumption from l level to k level
- Now assume that we want to identify the effect of U.S. tariff on employment in China
- What is the research design here?
- Can you interpret the identification assumption at k level?

Borusyak, Hull, and Jaravel (2022): Shock-level Equivalence

- The industry demand shocks g_k must be orthogonal with the industry-level unobservables $\bar{\epsilon}_k$, the average local supply shocks in different regions weighted by industry size
- Industries experiencing a rise in tariff should not face systematically different labor supply shocks in their primary markets
- Assume a U.S. tariff hits steel industry in China, which hits Hebei hard
- We should expect no labor supply shocks in Hebei, such as a change of enrollment quota in Gaokao at the same time

Borusyak, Hull, and Jaravel (2022): Shock-level Equivalence

- Now we have the following proposition

Proposition 1 in BHJ(2022)

The SSIV estimator $\hat{\beta}$ equals the second-stage coefficient from a s_k-weighted shock-level IV regression that uses the shocks g_k as the instrument in estimating

$$\bar{y}_k = \alpha + \beta \bar{x}_k + \bar{\epsilon}_k$$

where $\bar{v} = \frac{\sum_l s_{lk} v_l}{\sum_l s_{lk}}$ denotes an exposure-weighted average of a variable v_l

- This proposition 1 establishes the equivalence between the original and the shock-level regressions

Borusyak, Hull, and Jaravel (2022): Shock-level Equivalence

- We establish the consistency of this estimator under two assumptions:
  - Assumption 1: $E[g_k|\bar{\epsilon}, s] = \mu$, quasi-random shock assignment
  - Assumption 2: $E[\sum_k s_k^2] \rightarrow 0$, $Cov[g_k, g_{k'}|\bar{\epsilon}, s] = 0$, many uncorrelated shocks industries should not be too concentrated

Proposition 3 in BHJ(2022)

Suppose Assumptions 1-2 and some other regularity conditions hold, we have: $\hat{\beta} \xrightarrow{p} \beta$

- Identification is valid when shocks are random

Borusyak, Hull, and Jaravel (2022): Empirical Suggestions

- The first empirical suggestion is about the inference of the std err
- Adao, Kolesár, and Morales (2019) show that the traditional inference is incorrect since samples in the SSIV setting are intrinsically not i.i.d.
- Because there is common shock components g_k and ν_k in ϵ_l and z_l
- ϵ_l and z_l are mechanically correlated across observations
- The correlations are large for locations with similar industry shares

Borusyak, Hull, and Jaravel (2022): Empirical Suggestions

- Borusyak, Hull, and Jaravel (2022) show that the shock-level regression does not suffer from this
- You can directly use the traditional std err and CI estimated here
- A stata package can help you run this shock-level regression: *ssaggregate*

Borusyak, Hull, and Jaravel (2022): Empirical Suggestions

- The second empirical suggestion is about the descriptive test for IV validity
- A simple balance test is to regress some pre-determined control r_l on IV z_l
- r_l can be location level GDP, population etc...
- This can be combined with the Oster bound method
- Another balance test is to start from a industry shock-level confounder r_k
- Then construct location-level average $r_l = \sum_k s_{lk} r_k$
- Then run this average r_l on IV z_l

Borusyak, Hull, and Jaravel (2022): Empirical Suggestions

- Another possible way to implement the balance test is to transform everything to k level
- We can aggregate location l level confounder r_l to industry k level by $r_k = \frac{\sum_l s_{lk} r_l}{\sum_l s_{lk}}$
- Then we run this r_k on shock g_k
- Personally, I think this is more important than previous two
- Because it directly test the main assumption

Comparison of the Two Frameworks

- We have introduced two frameworks to understand Bartik IV
- The first is Goldsmith-Pinkham, Sorkin, and Swift (2020)
  - Equivalence: GMM with share as instrument, shift as weight
  - Research design: Exposure DID
  - Assumption: Locations with different shares have parallel trend
- The second is Borusyak, Hull, and Jaravel (2022)
  - Equivalence: Shock-level regression, shift as instrument, share as weight
  - Research design: Randomly assigned shocks
  - Assumption: Industries with large shocks do not have systematically different unobserved shocks in their primary market (location)

Comparison of the Two Frameworks

- When should we use these two frameworks?
- We should consider Goldsmith-Pinkham, Sorkin, and Swift (2020) when
  - Exogeneity comes from share
  - Emphasize differential exposure to common shocks (DID design)
  - Fixed small number of industries ($K = K^*, L \to \infty$)
  - Focus on shock exposure of several specific industries
  - Have some exposure shares tailored to the specific policy question
- We should consider Borusyak, Hull, and Jaravel (2022) when
  - Exogeneity comes from shift (shock)
  - We believe shocks are randomly assigned
  - Fixed small number of locations ($K \to \infty, L = L^*$)
  - Whenever the second-stage error ϵ_{lk} has a shift-share structure
    Mechanical correlation between Bartik IV and this error $\epsilon_{lk} = \sum_k s_{lk}\epsilon_k$

Application: Autor, Dorn, and Hanson (2013)

- The paper report this week is Autor, Dorn, and Hanson (2013)
- Impact of import from China on the local labor markets in the U.S., "China Syndrome"
- Goldsmith-Pinkham, Sorkin, and Swift (2020) and Borusyak, Hull, and Jaravel (2022) use this paper as an example
- To show how to apply their frameworks
- Please not only read the original paper, but also read the corresponding part in Goldsmith-Pinkham, Sorkin, and Swift (2020) and Borusyak, Hull, and Jaravel (2022)

Conclusion

- Bartik IV is constructed in a shift-share style
- It is widely used in spatial economics for trade and migration
- We illustrate two frameworks to understand it
  - Goldsmith-Pinkham, Sorkin, and Swift (2020)
  - Borusyak, Hull, and Jaravel (2022)
- When to use which framework really depends on the setting of our research

Conclusion

For Goldsmith-Pinkham, Sorkin, and Swift (2020)

- Bartik IV is equivalent to GMM with shares as instruments
- We should always control for location/time FE, or use change variables
- Bartik IV is similar to a policy exposure design, with initial shares as the exposures
- We can decompose Bartik IV to be weighted averages of single share instruments
- The Rotemberg weights show the importance of each single industry

Conclusion

For Borusyak, Hull, and Jaravel (2022)

- Bartik IV is equivalent to a shock-level regression with shifts as instruments
- The research design is based on the assumption of a series of randomly assigned shocks
- Be careful about the inference of the std err due to the serial correlation nature of the DGP $\Rightarrow$ A transformation to shock-level regression can avoid this issue

References

Adao, Rodrigo, Michal Kolesár, and Eduardo Morales. 2019. "Shift-share Designs: Theory and Inference." *The Quarterly Journal of Economics* 134 (4):1949–2010.

Autor, David H, David Dorn, and Gordon H Hanson. 2013. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." *American Economic Review* 103 (6):2121–2168.

Borusyak, Kirill, Peter Hull, and Xavier Jaravel. 2022. "Quasi-experimental Shift-share Research Designs." *The Review of Economic Studies* 89 (1):181–213.

Card, David. 2009. "Immigration and Inequality." *American Economic Review* 99 (2):1–21.

Goldsmith-Pinkham, Paul, Isaac Sorkin, and Henry Swift. 2020. "Bartik Instruments: What, When, Why, and How." *American Economic Review* 110 (8):2586–2624.