# Misfits in the Car Industry

## Why some firms offshore assembly

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May 9, 2018

# Who offshores and what do they offshore?

- Concern about the effects of offshoring on workers motivates a large body of empirical research.
- Pierce & Schott point to US firms reallocating production to China as a major cause of declining manufacturing employment.
  - Biggest increase in Chinese exports to US following WTO accession was for foreign affiliates.
  - WTO accession boost number of related-party import transactions.
- We ask what characteristics of a product make it more likely to be offshored to a lower wage country?
  - One obvious factor is sectoral cost competitiveness of the potential offshoring country.
  - A second key factor is variety-level misfit between product factor intensities and country factor abundances.
- We investigate these hypotheses, exploiting exceptionally detailed data from the car industry.

# Car production abroad: not just tariff-jumping anymore

1904: When Ford opened its first plant in Canada, initiating a pattern of *horizontal* multinational production in the car industry.

2009: Fiat CEO Marchionne boasts that a plant in Tychy, Poland assembled almost as many cars as the top 5 plants in Italy.

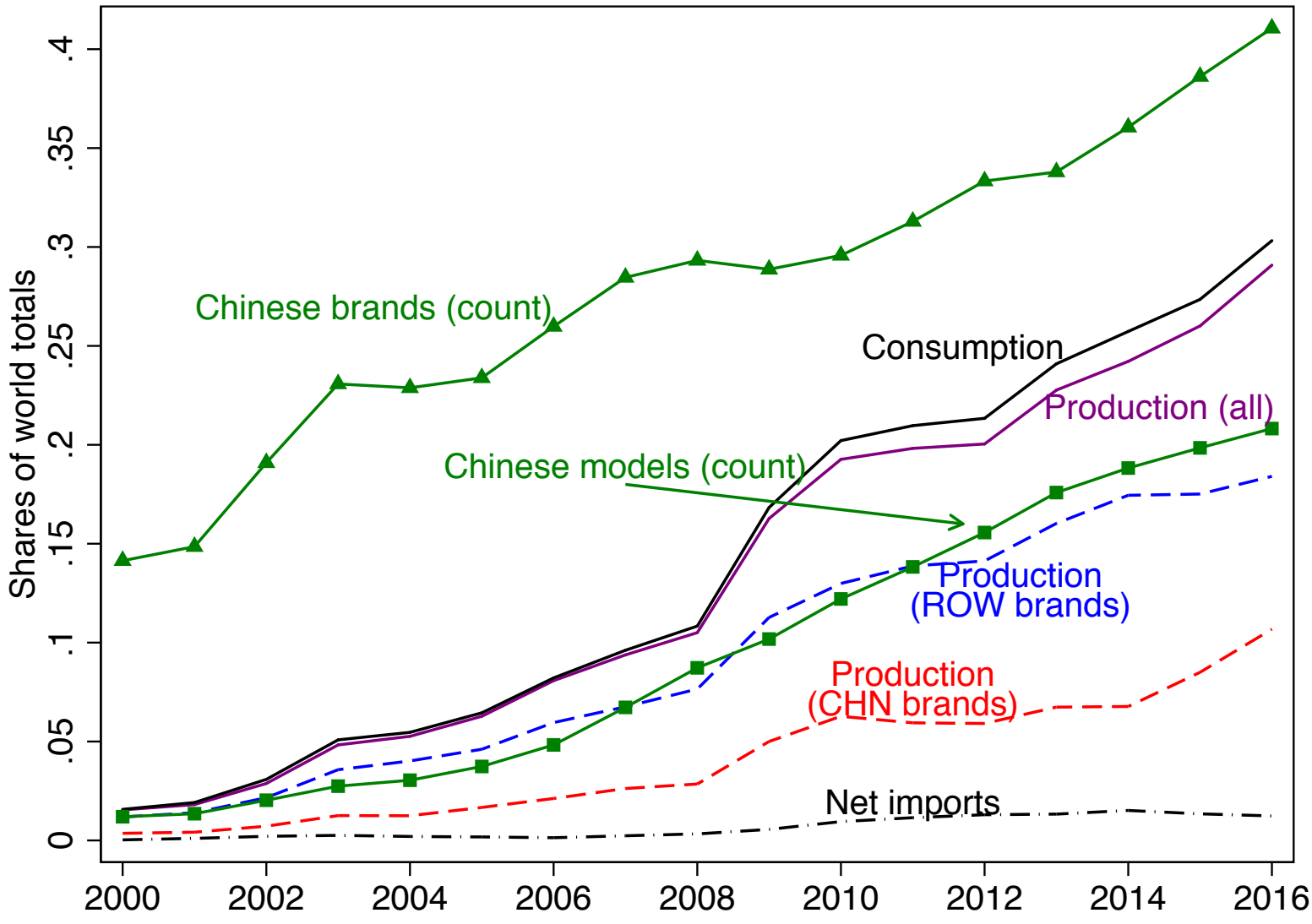
2010: President of France summons Renault CEO to explain its offshoring strategy; ordered to keep Clio assembly in France (not Turkey)

2014: Porsche announces assembly of Cayenne SUV moving to Slovakia (first time outside Germany).

2016: Ford to move small car production to Mexico (?)

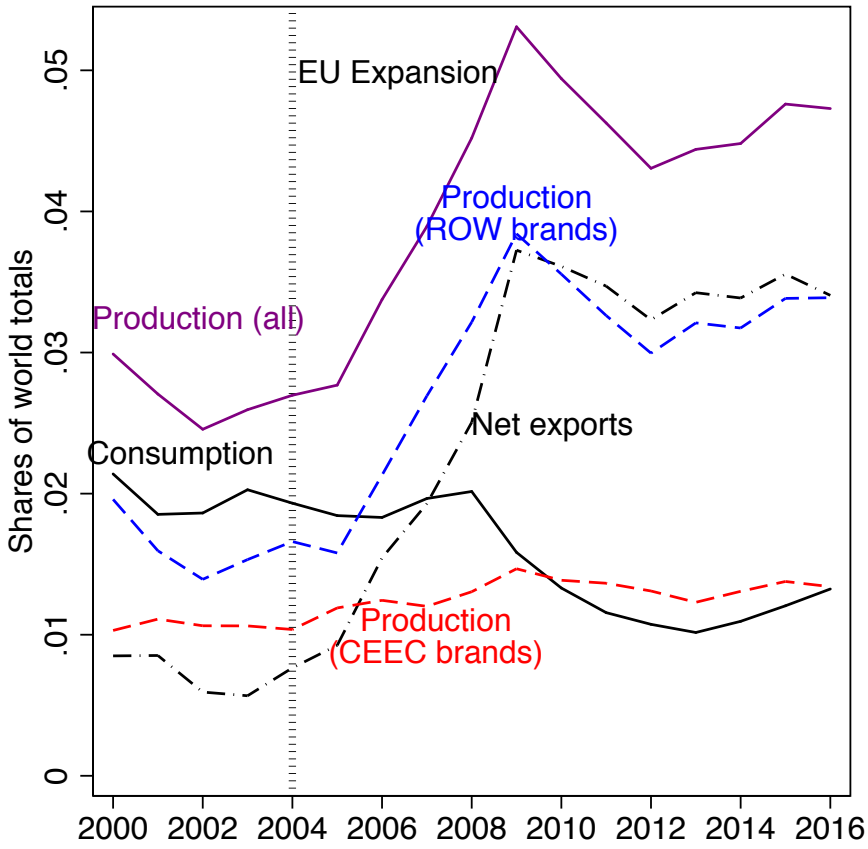
Future: Is the car industry embracing offshoring as with shoes, phones, etc.?

# Not offshoring to China

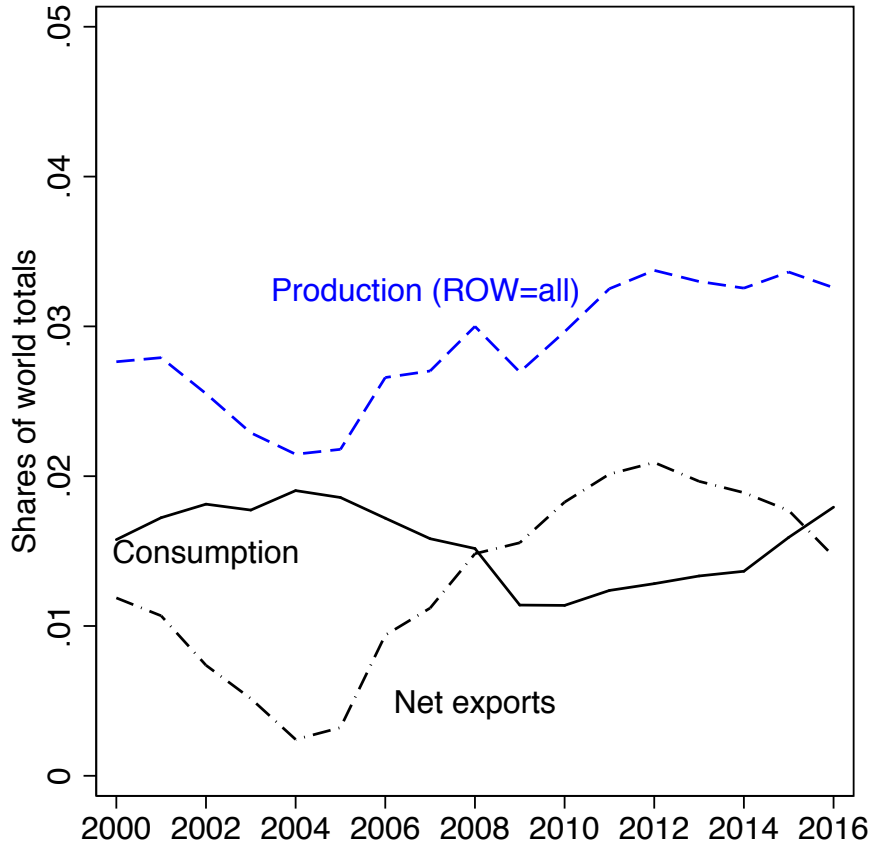


# Rising importance of the periphery

(a) Central & Eastern Europe




(b) Mexico



# What we do

1. **Describe**—with the most comprehensive data available—the rise of offshoring in the car industry from 2000–2016.
2. Propose a simple, easy-to-estimate framework in which comparative advantage dictates which companies offshore which car models.
3. Estimate **decision to offshore** assembly of 1000+ models of 151 car brands headquartered in 20 countries.
4. The chief explanatory variables are
   - "Assembly advantage" of country $\ell$, estimated in a triadic gravity equation (production in country $\ell$ of cars designed in country $i$, destined for purchase in country $n$.)
   - Model-level misfit: An interaction between a proxy for relative wages in the HQ country and a proxy for skill intensity of each car model.

# Richness of the IHS data

- We know price segment (hi/lo), size, and function of each model.
- For each model we know brand home, number of units by assembly location and destination.
- We use passenger cars only (drop commercial vehicles)
- Dimensions of the data (2016, after cuts)
  - 50 different assembly countries (almost all world production)
  - 74 different markets (countries that record brand/origin)
  - 151 brands (Renault) of 67 parents (Renault-Nissan) from 20 Headquarter countries
  - 1223 car models (Twingo)

# Defining Offshoring

Feenstra: "transfer of production overseas, whether it is done within or outside the firm"

Application to cars

- Focus on single "task": assembly of passenger cars
- Not talking about car parts or other issues in "slicing the value chain"
- Question: When should we consider overseas production to be *transferred*?
  - Just production abroad to serve home market? (narrow)
  - All overseas production? (broad)

# Narrow definition of offshoring: home-market focus

"Ghosn said very clearly that the Clio 4s corresponding to the French market will be made in France ...You can't ask Renault to make cars for Turkey in France, which would mean not selling any more cars in Turkey." (Claude Guéant, Sarkozy Chief of Staff, January, 18, 2010)

- A car is considered offshored if it is consumed in the home country but assembled in a different country.
- Offshoring corresponds to vertical MP but we will measure it using domestic sales in the denominator.
- Home is the country where the brand is headquartered or where it was founded.
- There is especially strong interest in offshoring to lower wage countries.

# Offshoring by the broader definition

- Despite its widespread use, offshoring lacks an agreed upon definition.
- Focus on the home market is natural, but...
- From a labour perspective, Fiat 500s made in Tychy are Fiats not made in Torino—no matter who ultimately buys them.
- The right definition depends on the cross-substitution possibilities.
- Our broad definition of offshoring is production outside the brand home divided by the brand's production in *all* locations.
- This includes vertical, horizontal and export platform MP.

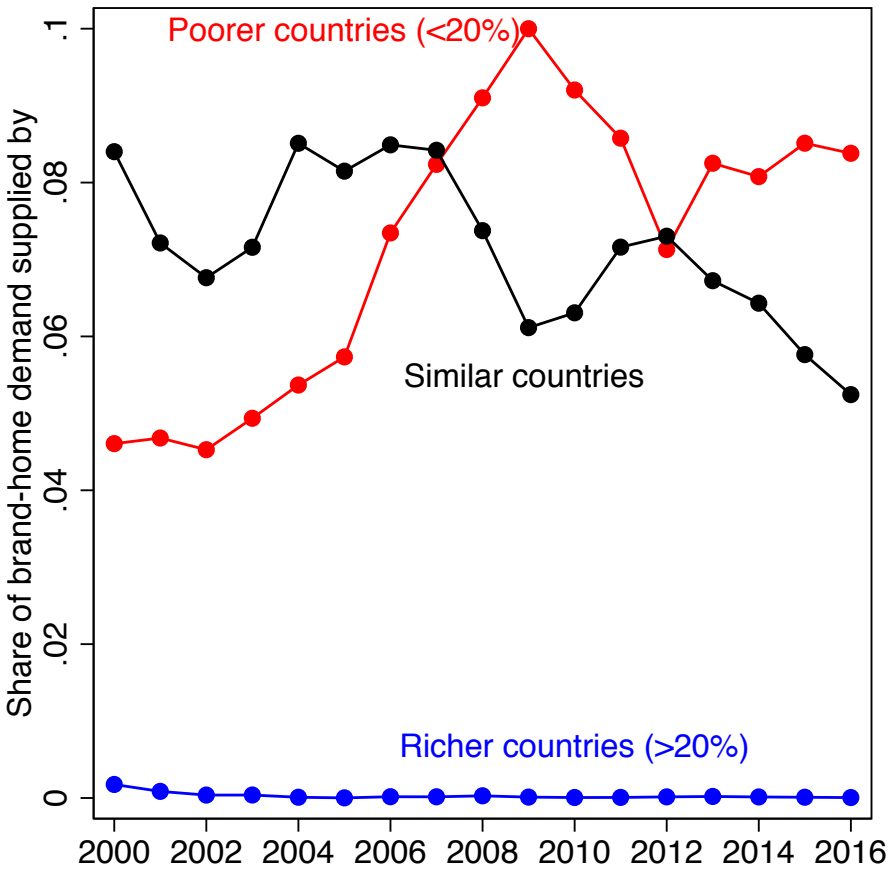
# The Twingo example

| Market: | FRA | | | COL | | | URY | VEN | ECU |
|---|---|---|---|---|---|---|---|---|---|
| Plant: | Flins | Novo | Mesto | Medellin | Novo | Mesto | Montevideo | Medellin | Medellin |
| Version: | I | II | III | I | II | | I | I | I |
| 2000 | 76622 | | | 1749 | | | 578 | | |
| 2001 | 78891 | | | 1927 | | | 476 | | |
| 2002 | 67588 | | | 3508 | | | | | |
| 2003 | 53146 | | | 4503 | | | | | |
| 2004 | 47699 | | | 5168 | | | | | |
| 2005 | 45594 | | | 7456 | | | | | |
| 2006 | 38133 | | | 9937 | | | | 2666 | 53 |
| 2007 | 8525 | 43618 | | 10069 | | | | 3377 | 34 |
| 2008 | | 65333 | | 6660 | | | | 960 | |
| 2009 | | 107456 | | 7756 | | | | 137 | 25 |
| 2010 | | 92183 | | 5565 | | | | | |
| 2011 | | 68236 | | 6780 | | | | 23 | |
| 2012 | | 39697 | | 3273 | | | | | |
| 2013 | | 39032 | | | | 277 | | | |
| 2014 | | 15824 | 26195 | | | 134 | | | |
| 2015 | | | 45425 | | | 2 | | | |
| 2016 | | | 40796 | | | | | | |

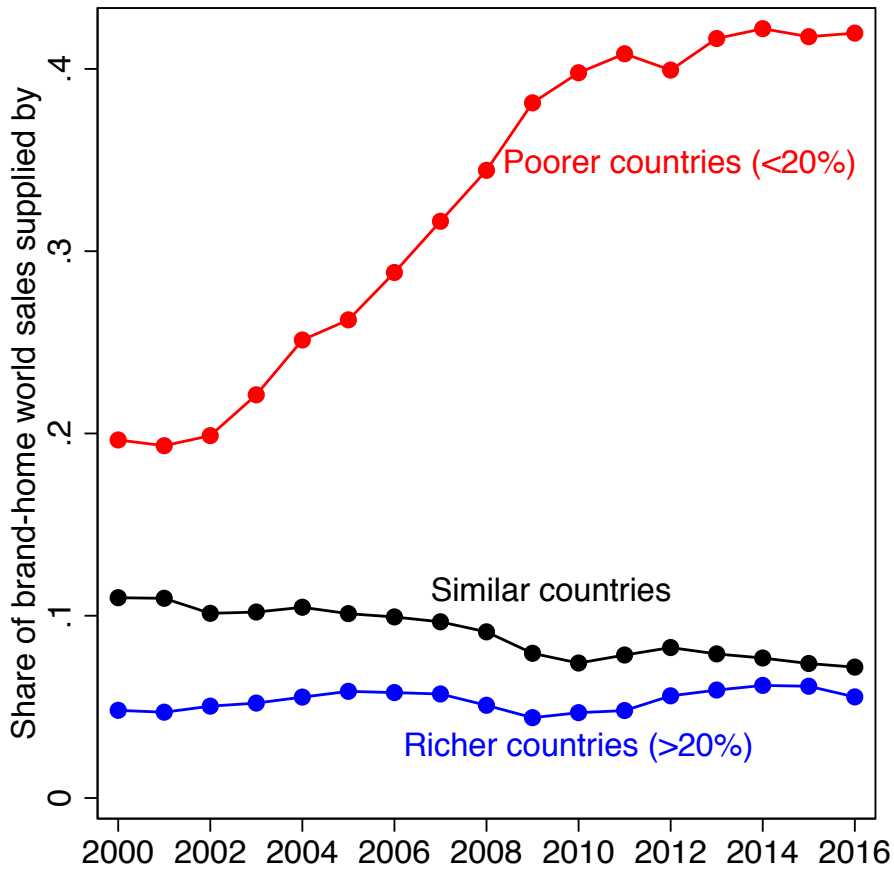
Note: The figures reported are total sales. All other countries where that car is continuously sold (Germany, Italy, etc.) exhibit the same sourcing pattern as for cars sold in France.

# World levels of offshoring by origin type

(a) Narrow def.




(b) Broad def.

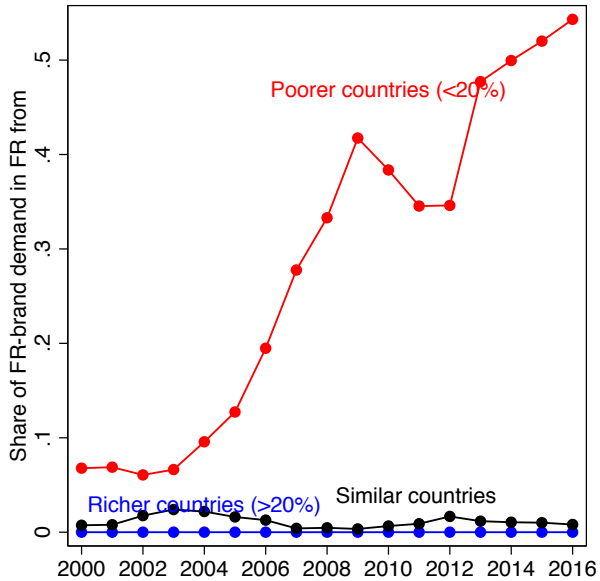


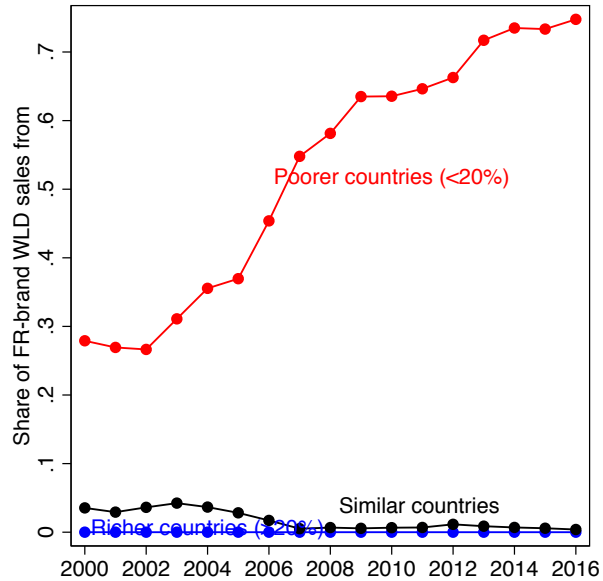
# Big offshorers:

## Narrow (home market)

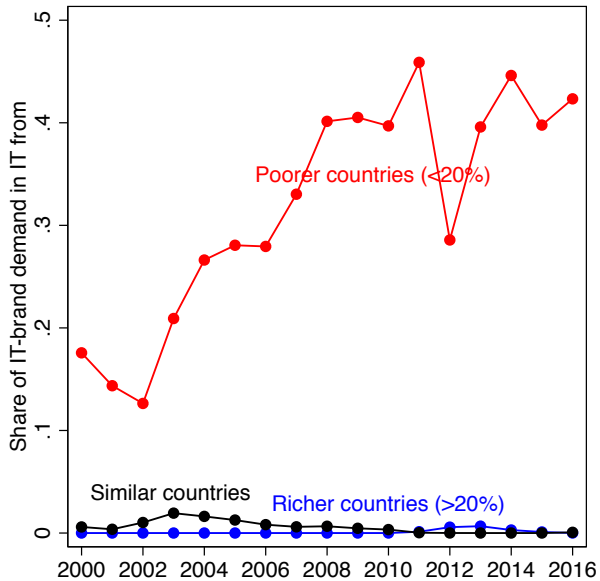
## Broad (all markets)

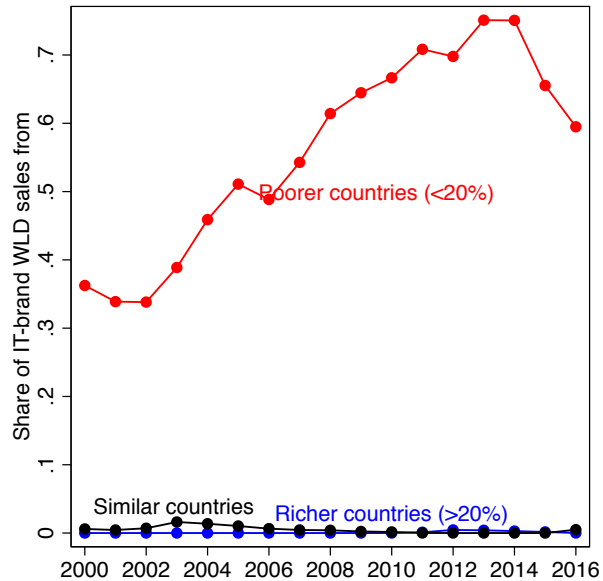
FRA




ITA



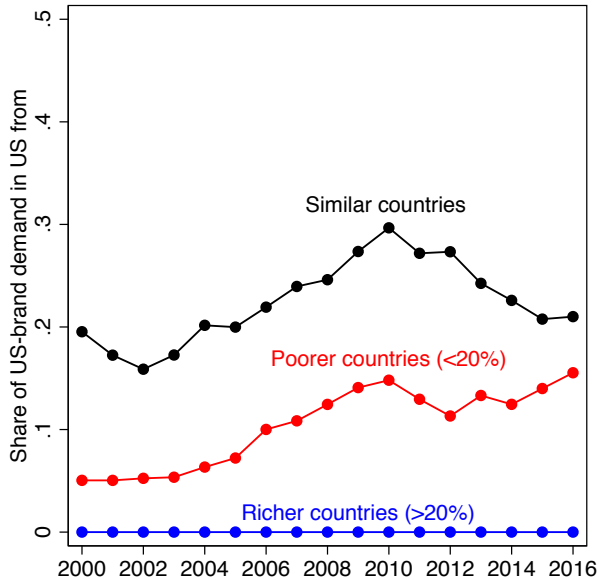



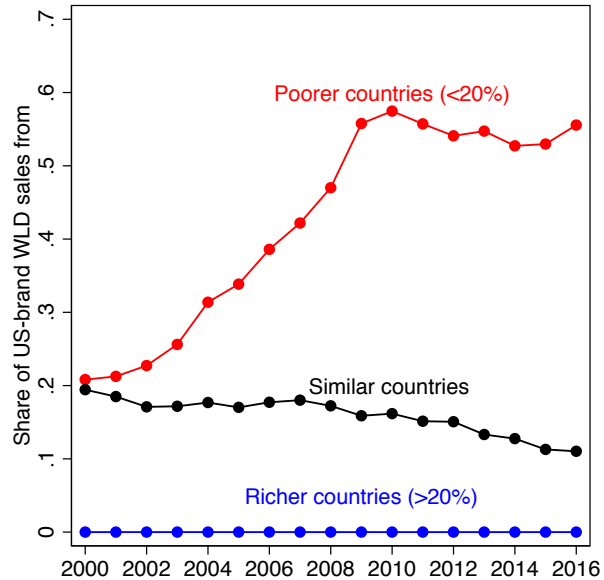
# Med. offshorers:

## Narrow (home market)

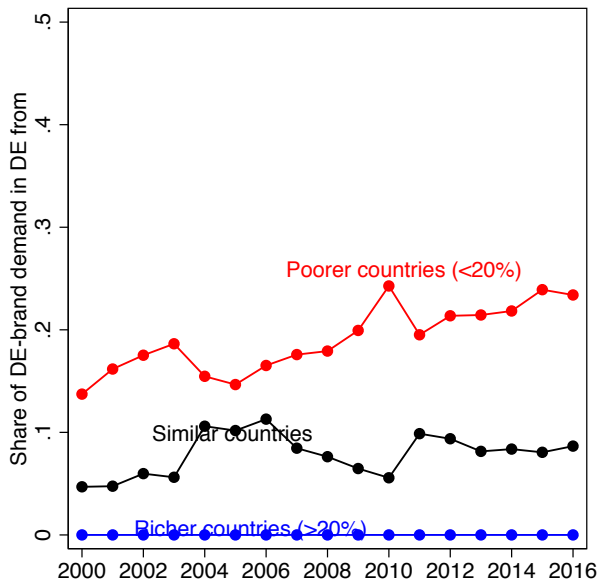
## Broad (all markets)

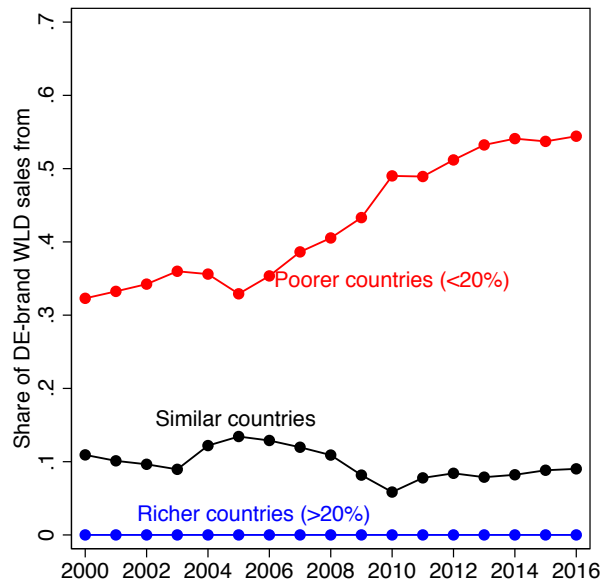
USA




DEU



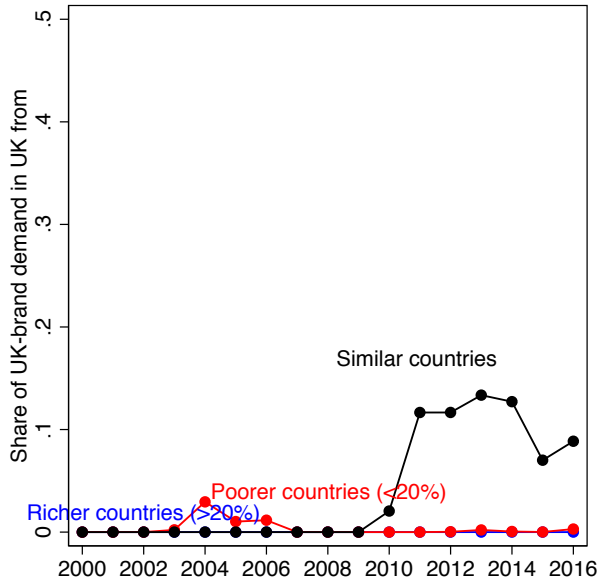



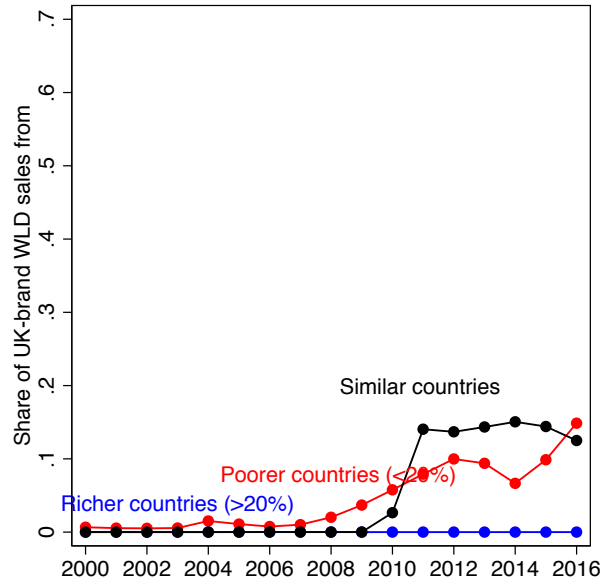
# Low offshorers:

## Narrow (home market)

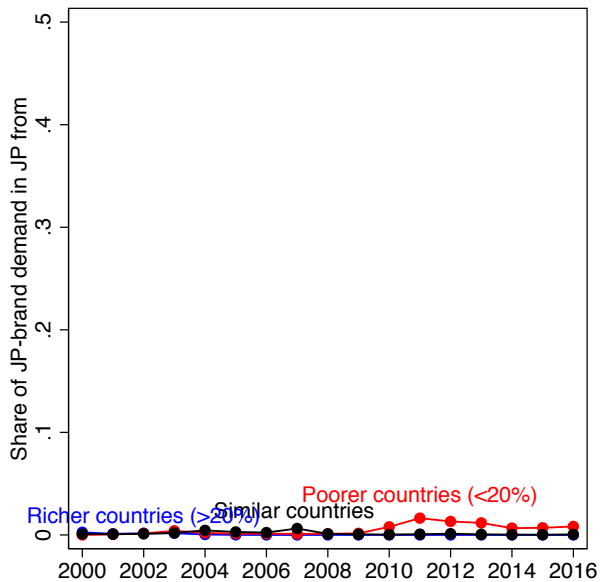
## Broad (all markets)

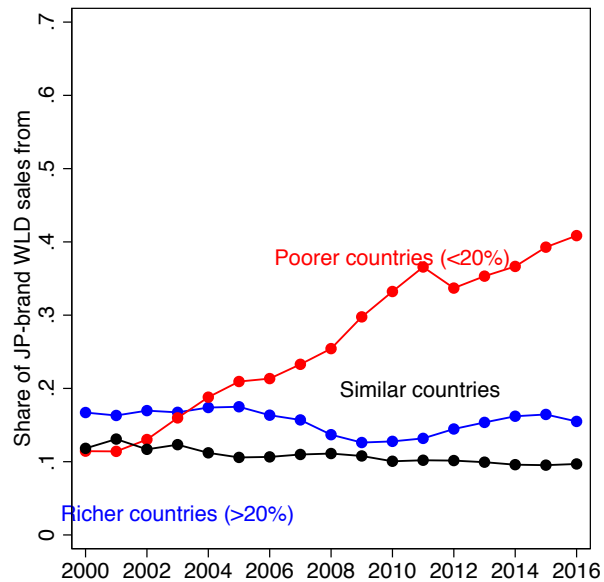
GBR



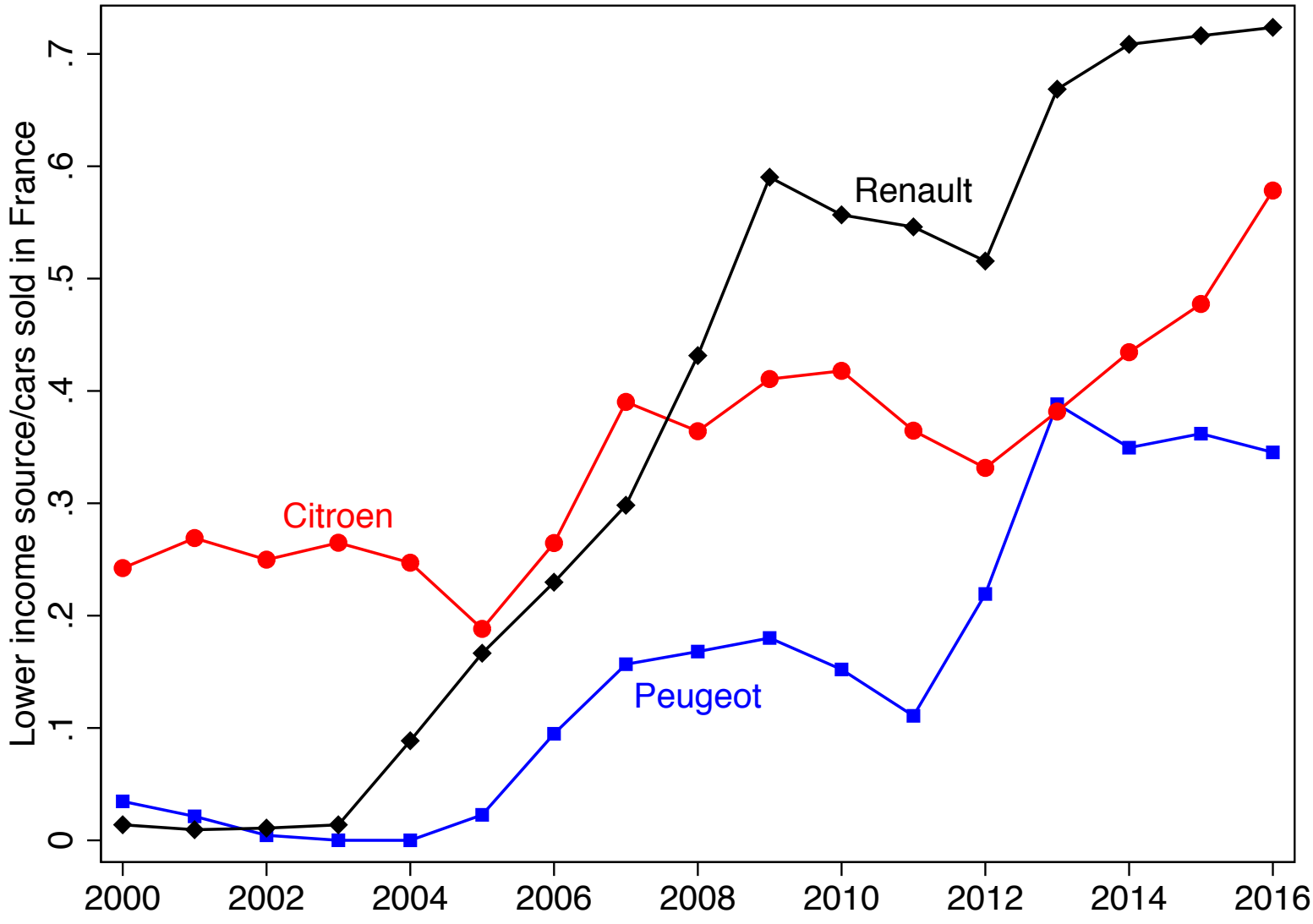




JPN

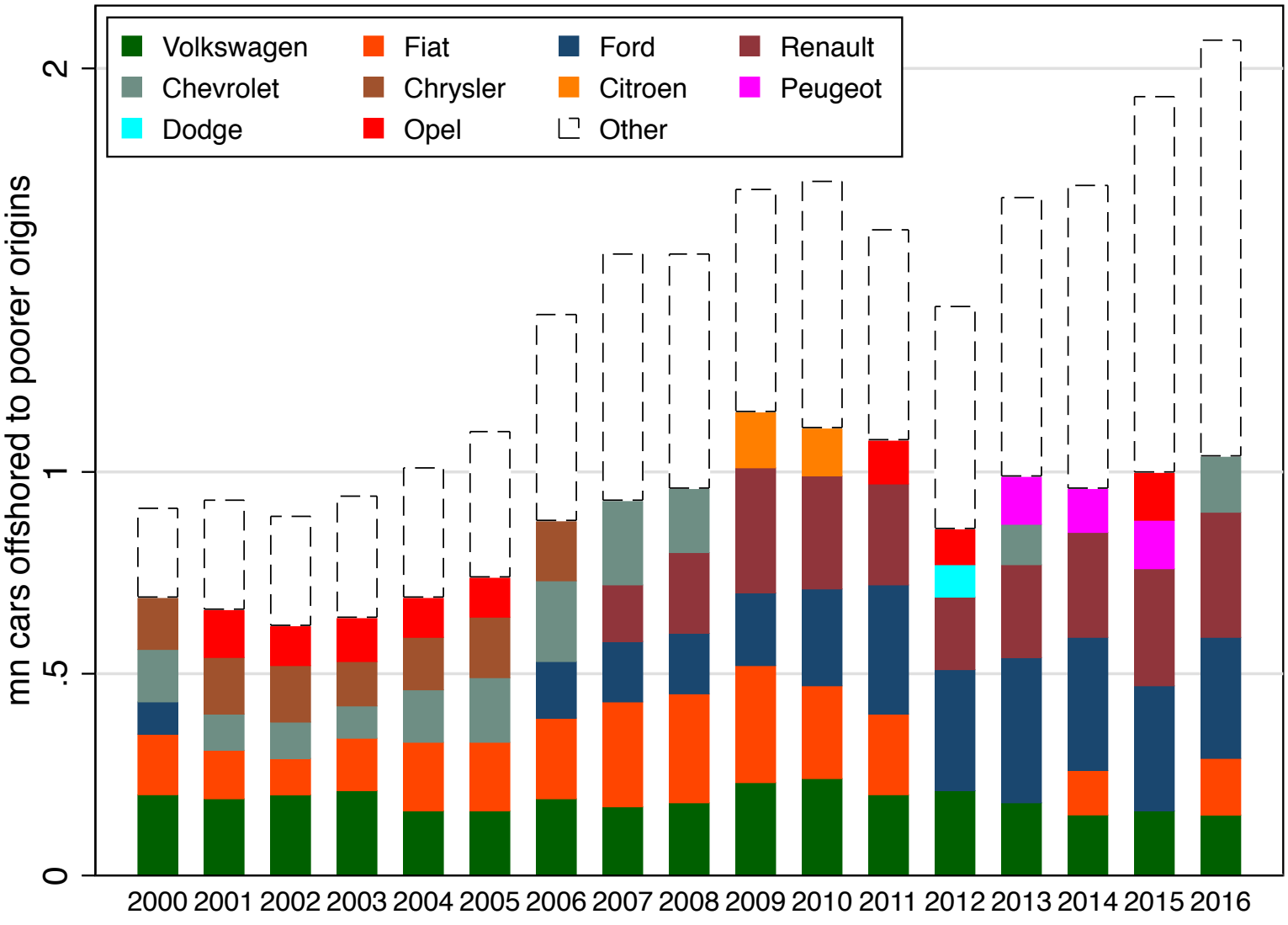


# Brand-level differences in narrow offshoring



# World's leading (narrow) offshorers



# What did we learn from all that?

- Offshored cars from poorer countries account for only small share of the HQ market—but it has doubled from 4% to 8%.
- Exceeds offshoring from similar income sources.
- Offshoring to poorer countries is much larger by the broad definition (40% of production) but it includes horizontal (market-seeking) MP that probably does not substitute much for home production.
- Massive heterogeneity in offshoring:
  - Similar countries and firms offshore in vastly different amounts.
  - The "unhappy few" (top 5 brands) account for the majority of offshoring.

# What factors drive offshoring?

- Why are some models offshored and others not?
- McCalman and Spearot (2013, JIE) point to low complexity, older vintages, and small scale.
- They considered only US truck makers offshoring to Mexico.
- Our data containing 25 HQ countries and 49 assembly countries allows us to investigate the role of country and model-level comparative advantage.

# Regression form of the "misfit" hypothesis

- The first factor underlying the offshoring decision is the general cost-competitiveness of the HQ country as an *assembler* of cars.
- The second factor is an interaction between the engineering-intensity of the car model and the level of development of the country.
  - Engineering intensity is assumed to be proportional to the fixed (non-market specific) component in car prices.
  - Country development is measured with log GDP per capita.
  - Misfit exists when a high income country assembles low-end car models.

$$\text{offs}_{m(i)t} = \Lambda(\beta_1 \widehat{\text{FEA}}_{it} + \beta_2 \ln p_m + \beta_3 \ln y_{it} + \beta_4 (\ln p_m \times \ln y_{it}) + \cdots)$$

$\beta_1 < 0$ supports the first factor; $\beta_4 < 0$ is predicted by the misfit hypothesis.

# Model-level assembly costs

- Domestic costs C-D in high (paid $w_H$) and low (paid $w_L$) skilled labour:

$$c(m) = \alpha \left( w_H^{z(m)} w_L^{1-z(m)} \right)^{\beta} p_I^{1-\beta} \exp(\epsilon(m))$$

- $z(m)$ is the cost share parameter for high-skilled worker
- Costs comprise labor with share $\beta$ and a basket of intermediate inputs priced $p_I$.
- $\epsilon(m)$: match between model $m$ and HQ country

$$\ln c(m) = \ln \alpha + z(m)\beta \ln w_H + (1-z(m))\beta \ln w_L + (1-\beta) \ln p_I + \epsilon(m).$$

- Offshorers pay shipping cost $\tau$ and management cost $\gamma$.

$$\ln c^*(m) = \ln \alpha^* + z(m)\beta \ln w_H^* + (1-z(m))\beta \ln w_L^* + (1-\beta) \ln p_I^* + \ln(\tau\gamma) + \epsilon^*(m).$$

# Offshoring probability: role of comparative advantage

It is convenient to introduce notation $\omega$ and $\kappa$, such that

$$\omega \equiv \ln\left(\frac{w_H}{w_L}\right) \quad \text{and} \quad \kappa \equiv \ln\alpha + \beta \ln w_L + (1-\beta)\ln p_I,$$
$$\omega^* \equiv \ln\left(\frac{w_H^*}{w_L^*}\right) \quad \text{and} \quad \kappa^* \equiv \ln\alpha^* + \beta \ln w_L^* + (1-\beta)\ln p_I^* + \ln(\tau\gamma).$$

The choice to offshore will be driven by cost minimization, such that

$$\begin{aligned}\text{Prob(offshoring)} &= \text{Prob}\left[\ln c^*(m) < \ln c(m)\right] \\ &= \text{Prob}\left[\kappa^* + z(m)\beta\omega^* + \epsilon^*(m) < \kappa + z(m)\beta\omega + \epsilon(m)\right] \\ &= \text{Prob}\left[\epsilon^*(m) - \epsilon(m) < \kappa - \kappa^* + z(m)\beta(\omega - \omega^*)\right].\end{aligned}$$

Offshoring more likely for unskill-intensive models of HQ countries with a relatively low skill premium (high skill abundance).

# Offshoring probability: theory to empirics

Assuming that $\epsilon^*(m) - \epsilon(m)$ is distributed logistically gives:

$$\text{Prob(offshoring)} = \Lambda\left[\kappa - \kappa^* + \beta z(m)(\omega - \omega^*)\right]; \quad \Lambda(x) = (1+e^{-x})^{-1}.$$

Three variables affect propensity to offshore:

1. Assembly advantage: $\kappa - \kappa^*$, proxied with $\widehat{\text{FEA}}_i$, FE of country $i$ as an assembly site from triadic gravity eqn.
2. Comparative advantage proxies inspired by Schott (2004):
   - $\omega - \omega^*$, relative costs of skilled and unskilled labor (wrt ROW) inversely related to skill abundance, proxied by GDP *per capita*.
   - $z(m)$, skill intensity of the car: Theory says with constant markups, $\mathbb{E} \ln p(m) = \beta\omega z(m) + \text{constant}$
     $\Longrightarrow$ $z(m)$ proxied by log price: $\ln p(m)$.

# Measuring $\ln p_m$ (model-specific prices)

- There are large destination $n$-level price effects (cars are much more expensive in DNK!).
- Therefore we run a two-dimension fixed effects regression:

$$\ln p_{mnt} = \text{FEM}_m + \text{FEN}_{nt} + \epsilon_{mnt}$$

- We set $\ln p_m \equiv \widehat{\text{FEM}}_m - \text{mean}(\widehat{\text{FEM}}_m)$
- The regression has 28 markets, 14 years and 81,727 observations. It estimates 1777 model-level fixed effects.
- For models with no price information, we use the average within 14 function-size-price segments identified using IHS.

# Assembly advantage from triadic gravity

- We use triadic gravity eqn. to estimate an assembly effect, $\text{FEA}_{\ell t}$, for each HQ country that applies to all models assembled there.
- Triadic gravity distinguishes trade flows by
  1. production origin (assembly country) $\ell$
  2. destination $n$ (consumption)
  3. design origin $i$ (headquarters)
- Market shares $Q_{i\ell nt}/Q_{nt}$ regressed on $\ell n$ and $i\ell$ frictions, HQ-dest-year FEs and assembly country-year FEs
- The control for HQ effects allows us to distinguish between Germany exporting cars because it is a good place to assemble or the home of good brands.
- Next we outline the underlying theory for the triadic gravity equation.

# Triadic ("restricted") gravity: theory (ARRY)

$X_{i\ell n}/X_n$ is the market share obtained by $\ell$-made cars of $i$-based brands in $n$. ARRY's equation (7) delivers this share as the product of two factors:

$$\frac{X_{i\ell n}}{X_n} = \psi_{i\ell n}\lambda^E_{in},$$

- $\psi_{i\ell n}$ is the probability that country $\ell$ is the minimum-cost location for a firm from $i$ serving market $n$
- $\lambda^E_{in}$ is the share of $n$'s expenditures spent on firms from $i$. We can leave $\lambda^E_{in}$ unspecified here because it forms part of a fixed effect in the empirical implementation of the triadic gravity.

# Sourcing probabilities

The probability $i$-based firms serving $n$ choose $\ell$ as supplier is

$$\psi_{i\ell n} = \frac{\left[T_\ell (w_\ell \tau_{\ell n} \gamma_{i\ell})^{-\theta}\right]^{\frac{1}{1-\rho}}}{\sum_k \left[T_k (w_k \tau_{kn} \gamma_{ik})^{-\theta}\right]^{\frac{1}{1-\rho}}}.$$

- $w_\ell$: variable factor costs (including parts)
- $T_\ell$, the common factor for "production technology" in $\ell$,
- $\tau_{\ell n}$: costs for shipping products from $\ell$ to $n$,
- $\gamma_{i\ell}$ costs for $i$-based firms to transferring HQ inputs to factories in $\ell$
- $\theta$ and $\rho$ are distributional parameters for unobserved productivity shocks

# Frictions affecting sourcing decisions

Frictions, $\tau_{\ell n}$ between factory and buyer, and $\gamma_{i\ell}$ between HQ and factory, are based on five determinants:

- Home ($\times \text{OECD}_\ell/\text{LDC}_\ell$): the reverse of a border effect.
- Distance & Contiguity, standard measures of spatial separation
- RTA, regional trade agreements such as NAFTA, EU, etc.
- Applied tariffs: $\ln(1+\text{tariff}_{\ell n})$ where $\text{tariff}_{\ell n}$ is the tariff rate relevant when exporting cars from $\ell$ to $n$ and $\ln(1+\text{tariff}_{i\ell})$ with $\text{tariff}_{i\ell}$ being an average of tariffs paid when importing car parts in $\ell$ from HQ country $i$.

Denoting the corresponding vector of marginal costs for trade and production as $\mathbf{g}^T$ and $\mathbf{g}^P$, trade and multinational production frictions are given by

$$\tau_{\ell n} = \exp(\mathbf{D}'_{\ell n}\mathbf{g}^T), \qquad \gamma_{i\ell} = \exp(\mathbf{D}'_{i\ell}\mathbf{g}^P)$$

# Triadic ("restricted") gravity: implementation

- use quantity shares $Q_{i\ell n}/Q_n$, with $Q_n \equiv \sum_i \sum_\ell Q_{i\ell n}$ in place of unobserved *value* market shares $X_{i\ell n}/X_n$ in ARRY.
- Unlike ARRY, we have multiple HQ countries and can estimate $\tau_{\ell n}$ separately from $\gamma_{i\ell}$
- Acknowledging unobserved/imperfectly measured frictions determinants, the moment condition to estimate is

$$\mathbb{E}\left[\frac{Q_{i\ell n}}{Q_n}\right] = \exp\left[\mathsf{FEA}_\ell + \mathsf{FES}_{in} + \mathbf{D}'_{\ell n}\widetilde{\mathbf{g}}^T + \mathbf{D}'_{i\ell}\widetilde{\mathbf{g}}^P\right]$$

$\widetilde{\mathbf{g}}$ coefficients multiply $\mathbf{g}$ by $-\theta/(1-\rho)$

# Triadic regression results

| | trade $\tau_{\ell n}$ | MP $\gamma_{i\ell}$ |
|---|---|---|
| home (OECD) | 1.454$^a$ | 2.807$^a$ |
| | (.367) | (1.019) |
| home (LDC) | 3.364$^a$ | 3.743$^a$ |
| | (.517) | (.855) |
| ln distance | -.536$^a$ | .081 |
| | (.11) | (.215) |
| contiguity | .339$^c$ | .063 |
| | (.18) | (.399) |
| RTA | .79$^a$ | .589 |
| | (.255) | (.567) |
| ln (1+tariff) | -9.285$^a$ | -5.759 |
| | (1.024) | (6.361) |

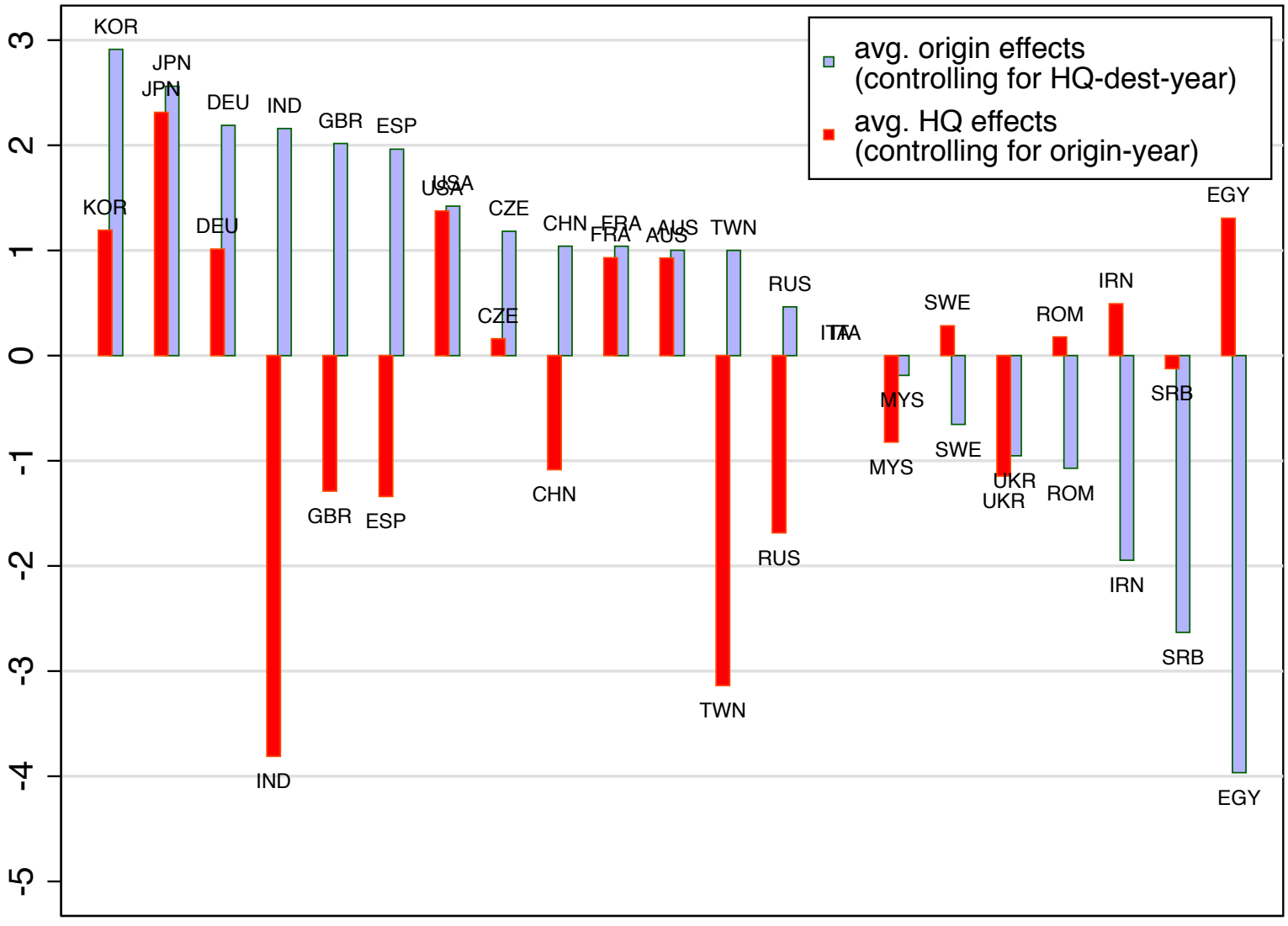
Notes: $R^2 = 0.91$, 200,735 observations (21 HQ, 52 assemblers, 76 markets, 17 years). PPML with $\ell t$ and *int* fixed effects.

Significance: $c$: $p < 0.1$, $b$: $p < 0.05$, $a$: $p < 0.01$.

# The identification of assembly and HQ effects

- Analogy with worker and firm fixed effects employer-employee data sets (AKM), also "places vs people" issue in econ. geo.
- Identification impossible without overlap.
  - Dual-job holders
  - Job-switchers
- Overlap in our data:
  - American workers assemble American, German, Japanese, and Korean brands.
  - Japanese brands are assembled in 31 countries.

# The best assembly and HQ countries for cars



# Offshoring regression specification

$$\text{offs}_{m(i)t} = \Lambda(\beta_1 \widehat{\text{FEA}}_{it} + \beta_2 \ln p_m + \beta_3 \ln y_{it} + \beta_4 (\ln p_m \times \ln y_{it}) + \cdots)$$

- $\ln y_{it} \times \ln p_m$ should have a negative effect on offshoring because high income countries have comp. adv. in high-end cars.
- Regressions run on narrow and broad definitions of offshoring "down" (assembled in a country with 20% lower per capita income than $i$).
- Offshoring of model $m$ in year $t$ is a function of the triadic production FE, the model price deviation and the income per capita deviation and their interaction.
- Additional controls included for scale (worldwide sales of model and brand), vintage (age of model and years left in program), as well as 13 segment and 13 year dummies.

# Control variables

- model scale (log output of the car model)
- brand scale (log output of all cars under the brand)
- model age, years left in program
- 14 segments based on function, size, and luxury

# Offshoring regressions: LPM

| sample: | all HQ countries | | only OECD HQ | |
|---|---|---|---|---|
| market: | home | all | home | all |
| ln model price | -0.062$^a$ | -0.211$^a$ | 0.019 | -0.234$^a$ |
| | (0.020) | (0.025) | (0.060) | (0.074) |
| ln model price $\times$ ln $y_{it}$ | -0.055$^a$ | -0.123$^a$ | -0.133$^a$ | -0.144$^b$ |
| | (0.012) | (0.016) | (0.042) | (0.064) |
| Observations | 12393 | 18701 | 9045 | 14871 |
| $R^2$ | 0.264 | 0.323 | 0.255 | 0.290 |
| count of models | 1760 | 2439 | 1142 | 1745 |

Note: Brand-clustered standard errors in parentheses. Significance levels: $c$: $p < 0.1$, $b$: $p < 0.05$, $a$: $p < 0.01$. Additional controls not reported here: headquarter-year and segment fixed effects, log sales at the model and brand level, age of model and years left in program.

# Offshoring fractions: narrow vs broad

| Fraction of model-years offshored | Home sales Count | Home sales Percent | World sales Count | World sales Percent |
|---|---|---|---|---|
| all | 1627 | 8.7 | 5866 | 31.37 |
| majority | 99 | .53 | 887 | 4.74 |
| minority | 170 | .91 | 1864 | 9.97 |
| none | 10497 | 56.13 | 10084 | 53.92 |
| n/a* | 6308 | 33.73 | | |

* n/a occurs under the narrow definition of offshoring because of model-years not sold in the home market of the model's brand.

Since 1% (narrow def.) and 15% (broad def.) of offshoring fractions lie between 0 and 1, we use fractional logit, $\Lambda()$

# Offshoring regressions: main effects & interaction

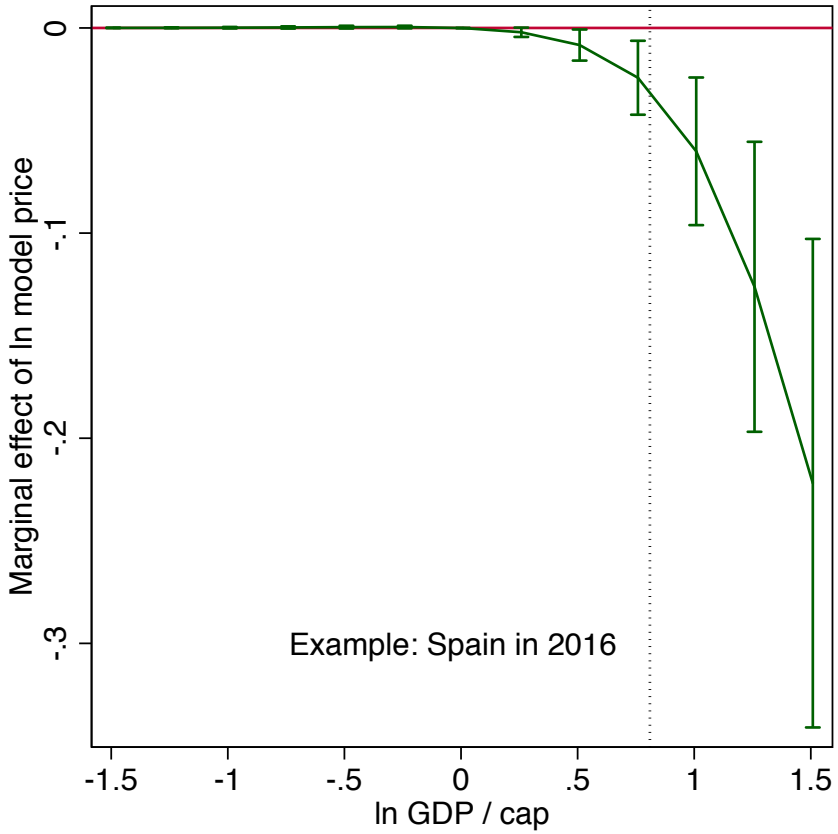
| method: | OLS | | Fractional logit | | |
|---|---|---|---|---|---|
| sample: | all HQ countries | | | only OECD HQ | |
| market: | home (narrow) | | all | home | all |
| HQ comp. adv. ($\widehat{\text{FEA}}_{it}$) | -0.036$^b$ | -0.607$^a$ | -0.198 | -0.601$^a$ | -0.326$^b$ |
| | (0.014) | (0.217) | (0.136) | (0.222) | (0.150) |
| frictions ($\ln \tau_{it}\gamma_{it}$) | -0.017 | -2.311$^c$ | -0.266 | -2.403$^c$ | -0.210 |
| | (0.025) | (1.205) | (0.224) | (1.293) | (0.424) |
| ln model price | -0.013 | 0.560 | -1.286$^a$ | -0.119 | -1.881$^a$ |
| | (0.018) | (1.058) | (0.273) | (1.699) | (0.506) |
| ln $y_{it}$ | 0.046$^c$ | 2.990$^b$ | 0.909$^a$ | 2.837$^b$ | 0.183 |
| | (0.023) | (1.271) | (0.244) | (1.332) | (0.310) |
| ln model price $\times$ ln $y_{it}$ | -0.029$^b$ | -1.744$^b$ | -0.852$^a$ | -1.236 | -0.532 |
| | (0.014) | (0.819) | (0.260) | (1.211) | (0.507) |
| Observations | 11796 | 11796 | 18076 | 9039 | 14864 |
| $R^2$ | 0.107 | 0.244 | 0.315 | 0.229 | 0.292 |
| count of models | 1726 | 1726 | 2405 | 1142 | 1745 |

Brand-clustered std. err. in (). Signif.: $c$: $p < 0.1$, $b$: $p < 0.05$, $a$: $p < 0.01$

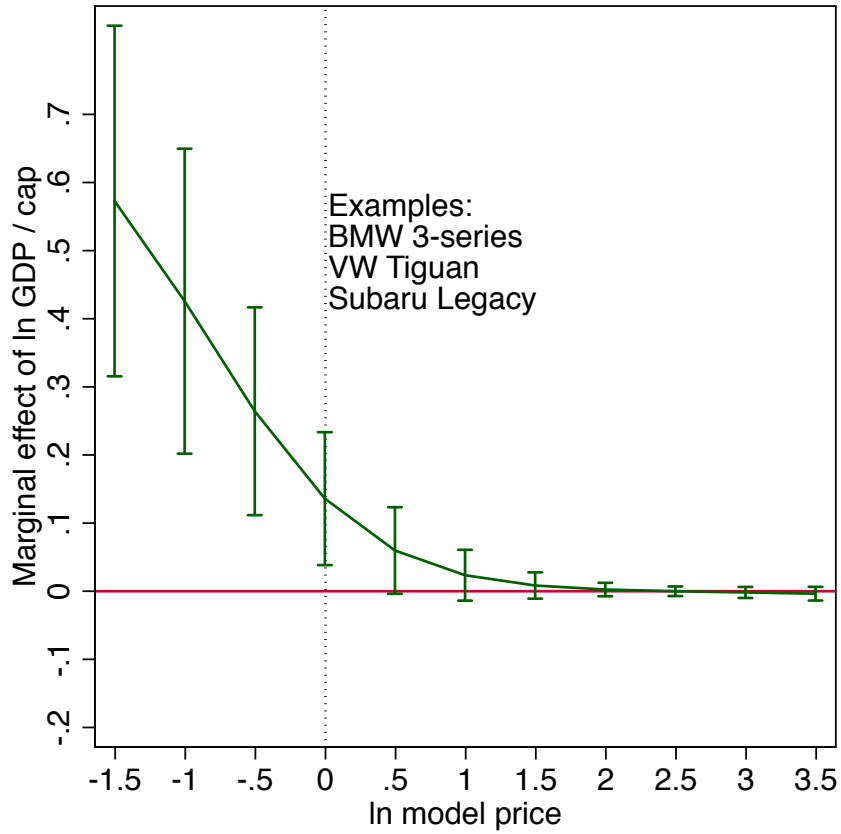
Additional controls not reported here: year, segment, scale, vintage

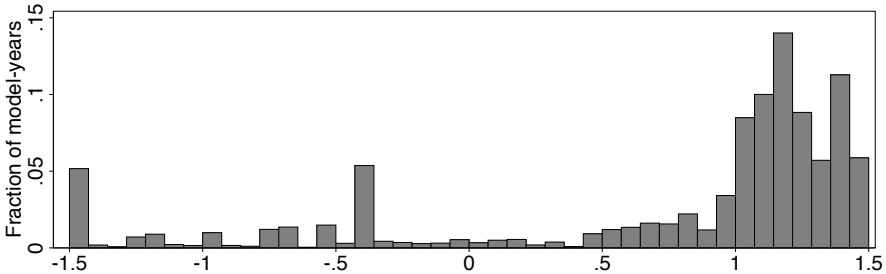
# Marginal effects of interacting comp. adv. factors

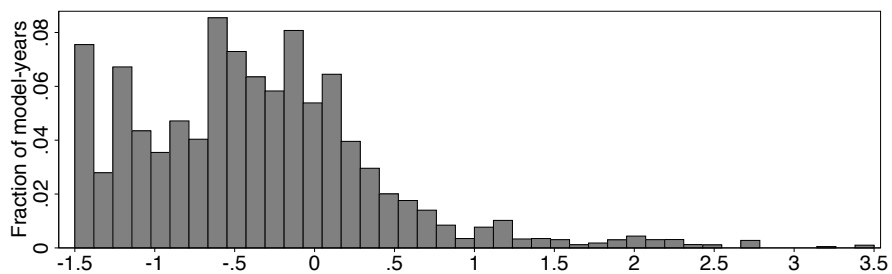
(a) Model price



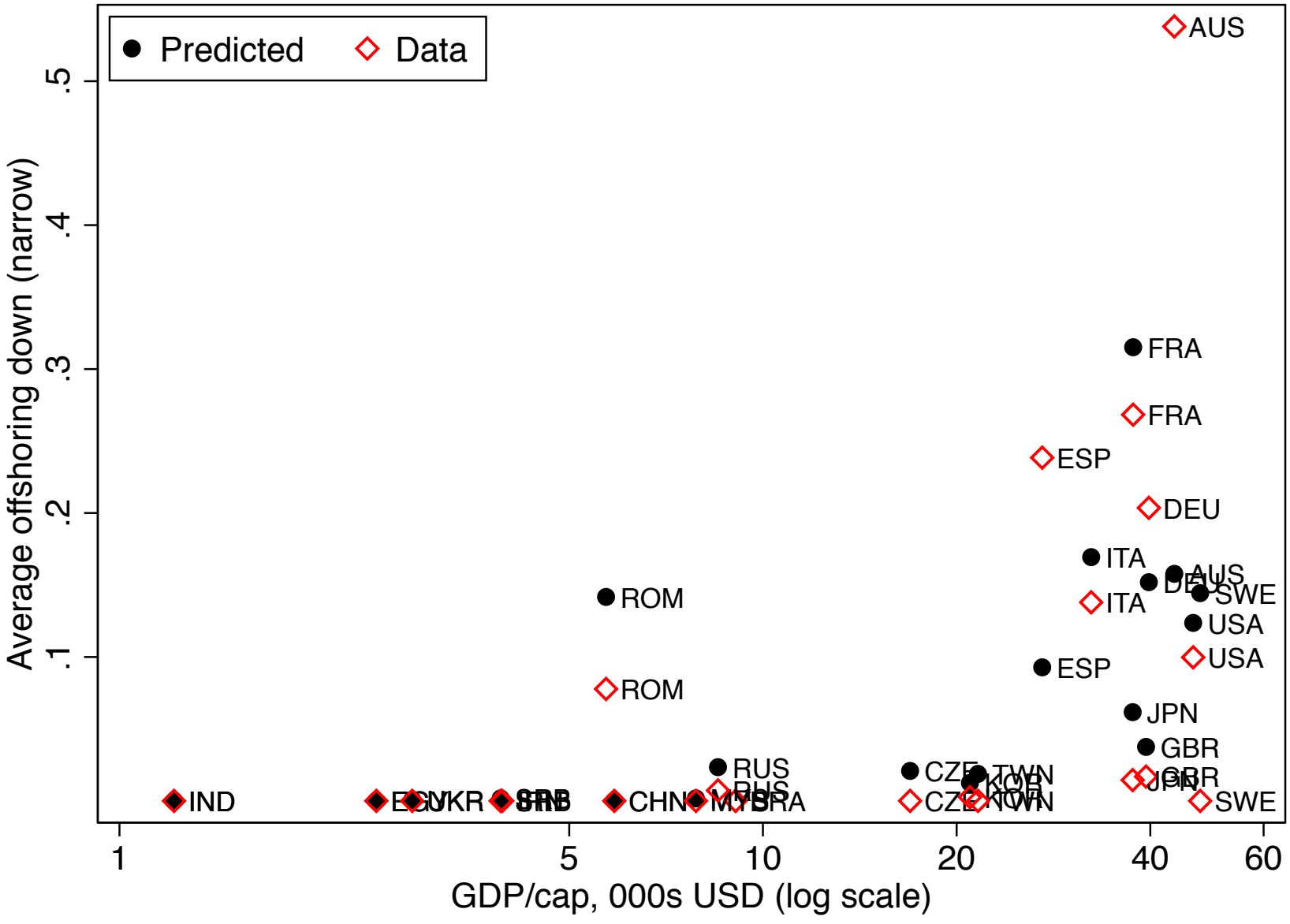

(b) GDP per capita



# Offshoring is for the rich



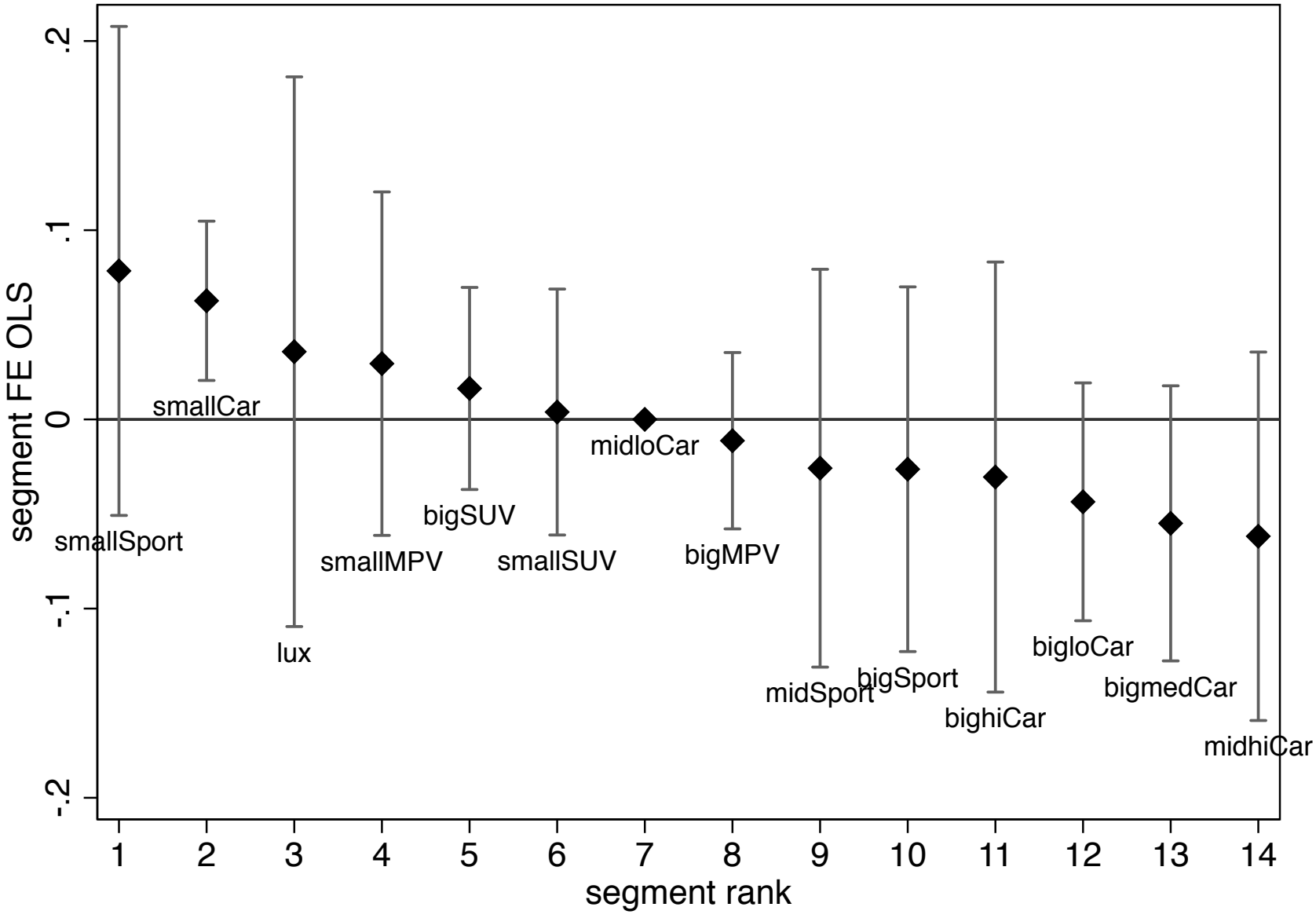
# Observations on misfit

- For countries richer than Spain, increasing model price decreases offshoring.
- For cars cheaper than BMW 3-series, increasing per capita income increases offshoring.
- Seat (VW sub.) the only Spanish brand produces majority cars in Spain but offshores a majority of models.
- On 20 October 2017, Holden (GM sub.) closed its last Australian plant. The brand continues as an importer of vehicles (100% offshoring).
- The model accurately predicts offshoring by France, Italy, UK, and USA.
- Germany should offshore a little less and Japan should offshore more...

# Comparison to McCalman and Spearot

- M&S findings on the Mexican production share of US trucks
  - Scale: Above median, less likely to be offshored.
    Us: model scale has ≈no effect, brand scale +
  - Age: Varieties less likely to be offshored in 1st year.
    Us: age has ≈no effect
  - Price: only price residuals matter; they enter negatively.
    Us: negative if per-capita income is high
  - Complexity: reduces offshoring.
    Us: no direct analogue available in our data (price?)
- M&S have data on US and Mexico only so they could not look at national comparative advantages, or the interaction between development and prices.
- M&S data set has sales in Canada and US only so can't calculate our "broad" offshoring.

# Segment effects



# Conclusions

- Offshoring assembly to lower wage countries is growing
  - but not to the usual suspects (China, India),
  - and not by all brands
    (top 5 brands do $\approx 2/3$ narrow offshoring),
  - and remains small share of home-market sales (8%).
  - Broad offshoring down is big (40% of global prod.) but oft-motivated by market access.
- Features that make a model likely to be offshored for the home market:
  - HQ country has cost disadvantage in assembly.
  - **Misfit**: low-price model from a high-income country