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Estimating Hedonic Price Indices for Ground Vehicles (Presentation)

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Estimating Hedonic Price Indices for Ground Vehicles

David Tate and Stan Horowitz

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Cost Analysis and Research Division

IDA | Estimating Price Indices

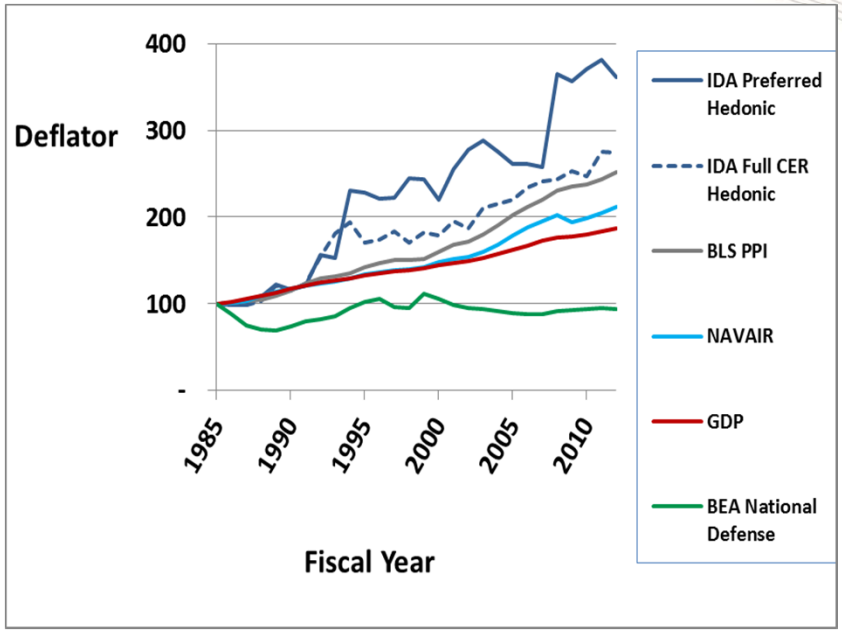
- Price indices are normally estimated by comparing the observed prices of identical goods in successive years
- This is easy when goods don't change much from year to year
  - Milk, gasoline, haircuts, …
- When the characteristics of products for sale change too quickly, we need to correct for quality changes to estimate real price growth
  - Computers, cell phones, military aircraft…

Quality-Adjusted Price Indices

- There are two main approaches to quality-adjusted price indices
  - Estimate the amount of price change due to new features for each new product on a case-by-case basis; assign any additional change to real price growth
  - Construct a ***hedonic*** model of price change that predicts price as a stable function of quality attributes; use annual fixed effects to capture cumulative real price growth

IDA | Previous Work

- Earlier work at IDA looked at military aircraft prices
- Published price indices disagreed wildly
- Indices from BEA estimated near-zero real price growth for decades



- IDA identified a potential systematic bias in those estimates, and estimated much higher price growth for a fixed quality level
- The IDA methodology made extensive use of lot-by-lot aircraft empty weight as a proxy for unobserved quality improvements

IDA | Ground Vehicle Prices

- The goal of this work was to extend the IDA methodology to estimate a hedonic price index (or indices) for military ground vehicles
- Available data had uneven reliability and varying definitions of "price"
  - Selected Acquisition Report – total cost/quantity
  - President's Budget – vehicle-only cost/quantity
  - MRAP contract data from CAPE-CA
  - Contract announcements from infoBASE
  - Jane's, FAS, contractor websites, etc.

IDA | Hedonic Specification

- The best hedonic model specification used 8 quality variables
  - 3 continuous
  - 5 binary
- Lot size
- Learning by doing
  - Only relevant for 2 out of 40+ vehicle types
- Log–log specification

- Power density (hp /ton)
- Top speed
- Ground pressure (psi)
- Tracked?
- Combat?
- Turret?
- Armored?
- Derivative design?

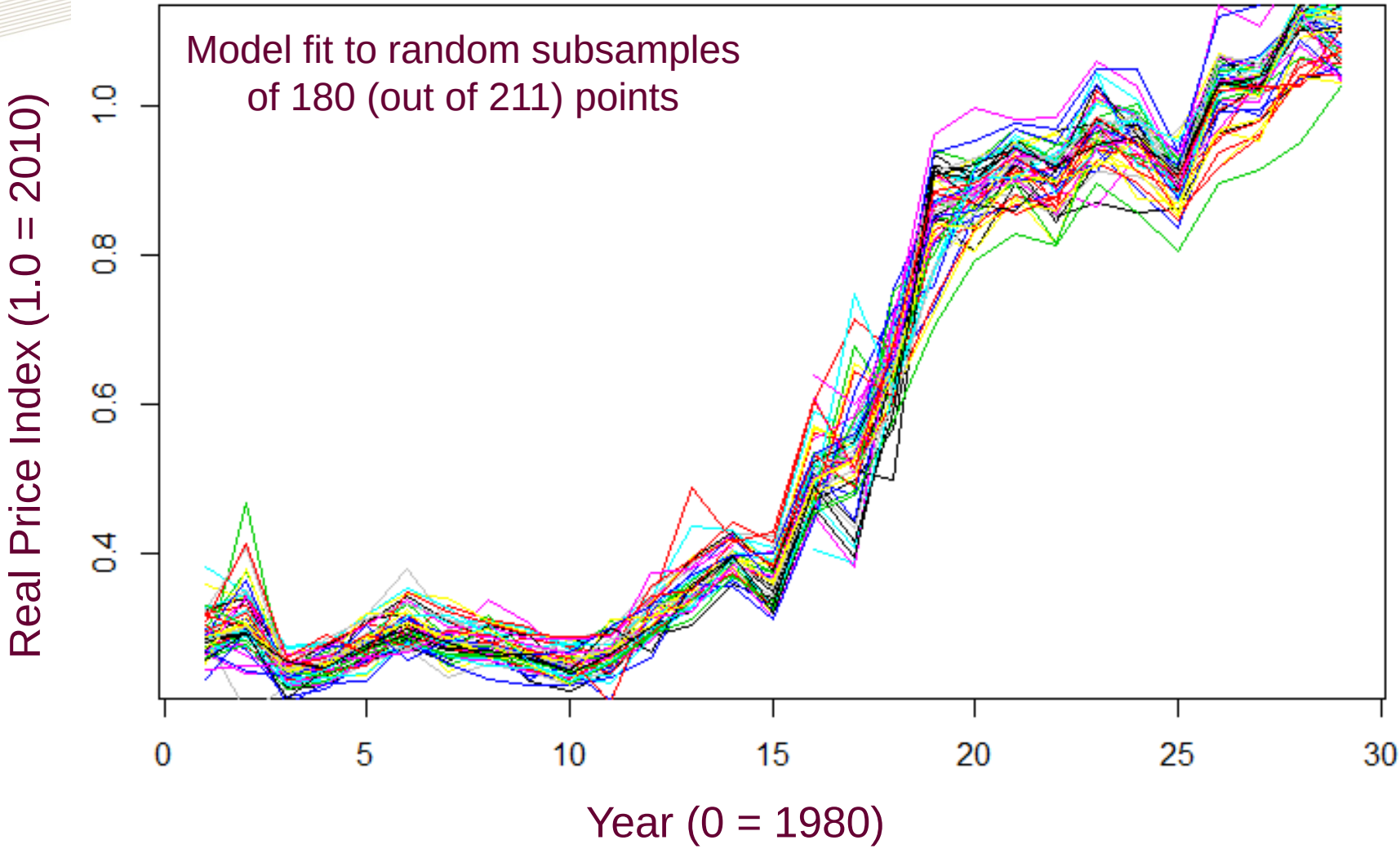
IDA | Predictors Highly Significant…

Parameter	Estimate	Standard Error	
(Intercept)…	9.35	1.35	***
log(Top Speed)…	–2.28	0.26	***
log(Ground Pressure)…	–0.94	0.13	***
log(Gross Vehicle Weight)…	0.93	0.06	***
Armored?…	0.93	0.10	***
Tracked?…	–1.66	0.26	***
Combat?…	0.78	0.06	***
Turret?…	0.49	0.09	***
Derivative?…	–0.28	0.07	***
log(Lot Size)…	–0.07	0.01	***
M9_ACE learning slope…	–0.17	0.04	***
M992_FAASV learning slope…	–0.10	0.03	***

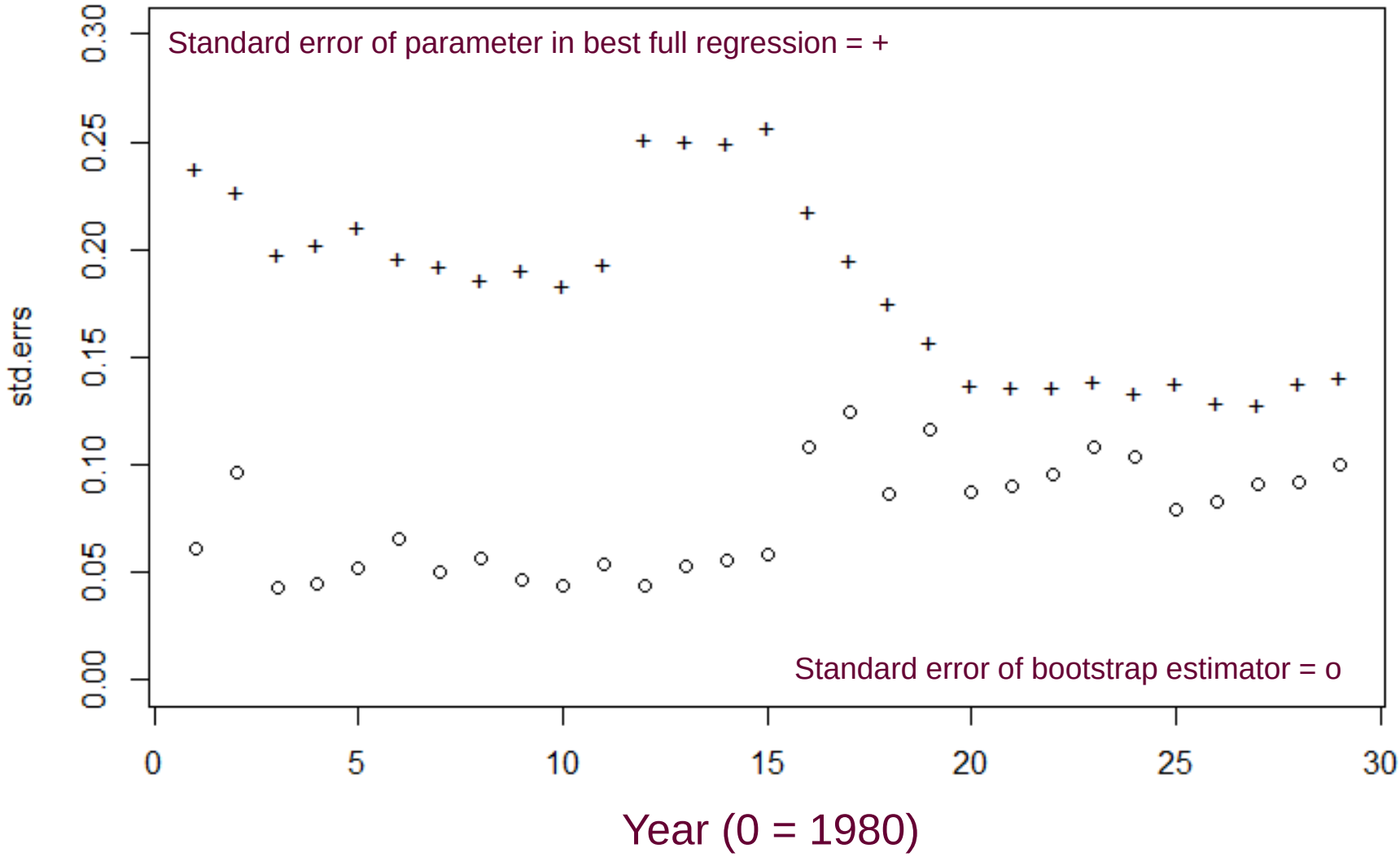
Residual SE…	0.198
Degrees of freedom…	139
Adjusted R^2…	0.975

All p-values < 10^{-5}

IDA | Annual Fixed Effect Estimates Were Not Robust



IDA | Bootstrapping Reduced the Fixed Effect SE



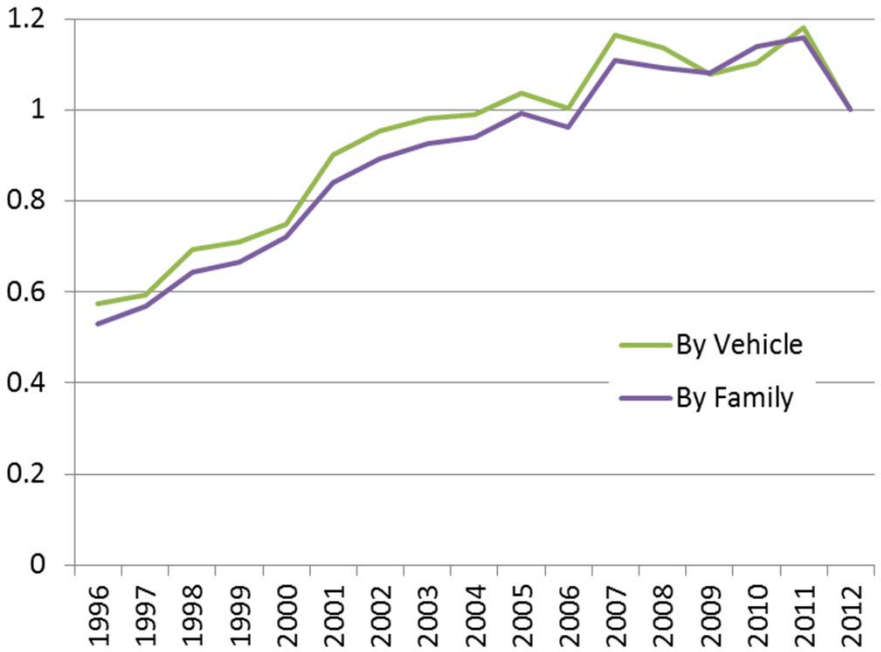
IDA | But there were some issues

- "Negative learning"
  - Most systems show lot-by-lot unit price growth
  - Naïve regression estimates 15% overall annual average
  - Suggests unobserved quality improvements
  - In the aircraft work, year-over-year weight growth was highly significant – proxy for quality improvements
- Price index estimation sensitivity
  - The estimated annual fixed effects are not robust with regard to either subsample or model selection
    - Many models with similar fit, very different annual fixed effects
  - It is possible to get a very good fit without any annual fixed effect terms – what does this indicate?

IDA | Alternative Formulation: The "Pure Price" Model

- Assume that each vehicle model is characterized by
  - An initial unit price
  - An initial quality level
  - A production rate price dependency
  - An unobserved implicit quality growth rate
    - Version 1 – constant by vehicle *family*
    - Version 2 – constant by vehicle *type*
- Estimate unit price as a function of these parameters plus annual fixed effects

IDA | Results in More Stable and Credible Estimates



~ 5.1% average annual price growth

Year	Index (by vehicle)	Index (by family)
1996	48.6%	45.7%
1997	50.3%	49.1%
1998	58.9%	55.5%
1999	60.2%	57.4%
2000	63.4%	62.2%
2001	76.4%	72.6%
2002	80.8%	77.0%
2003	83.2%	80.0%
2004	84.0%	81.2%
2005	88.0%	85.6%
2006	85.0%	83.1%
2007	98.7%	95.8%
2008	96.3%	94.4%
2009	91.3%	93.3%
2010	93.5%	98.3%
2011	100.0%	100.0%

IDA | Summary

- Military vehicle characteristics change too quickly for ordinary price index calculations to apply
- Hedonic models make assumptions that probably aren't true for military vehicles
  - That we know the relevant quality attributes, and have good lot-by-lot data for them
  - That the value to the buyer of a given quality attribute is constant over time
- The pure price model gives stable and credible estimates, but requires one iffy assumption
  - That unobservable quality growth is roughly constant by vehicle type/family

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Backup

IDA | Problem Background

- The Weapon Systems Acquisition Reform Act of 2009 (WSARA) tasks OSD(CAPE) with "…assessing and updating the cost indexes that the Department of Defense employs to ensure the use of realistic cost estimates."
- OSD(CAPE) asked IDA/CARD to assist in assessing the accuracy of existing price indices for various types of system

IDA | What are price indices used for?

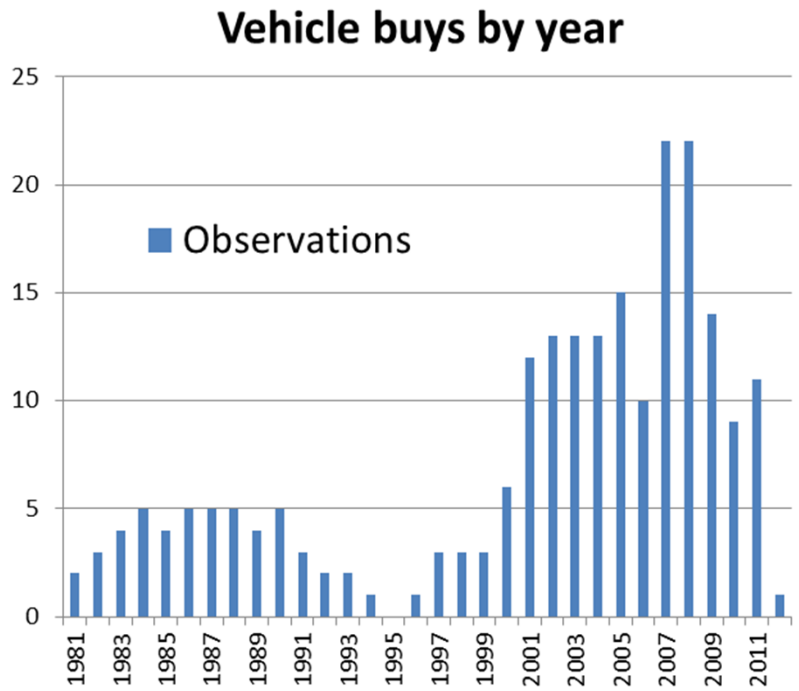
- Program offices use price indices to estimate the future budgetary requirements of acquisition programs in then-year dollars
- Oversight organizations use price indices to distinguish sector-specific real price growth from general inflation
- OMB uses price indices to estimate the relative burden of defense procurement (or subsets thereof) on the economy
- DoD leadership would like to be able to distinguish changes in the price of military capability from changes in the amount of capability demanded

IDA | Data Set

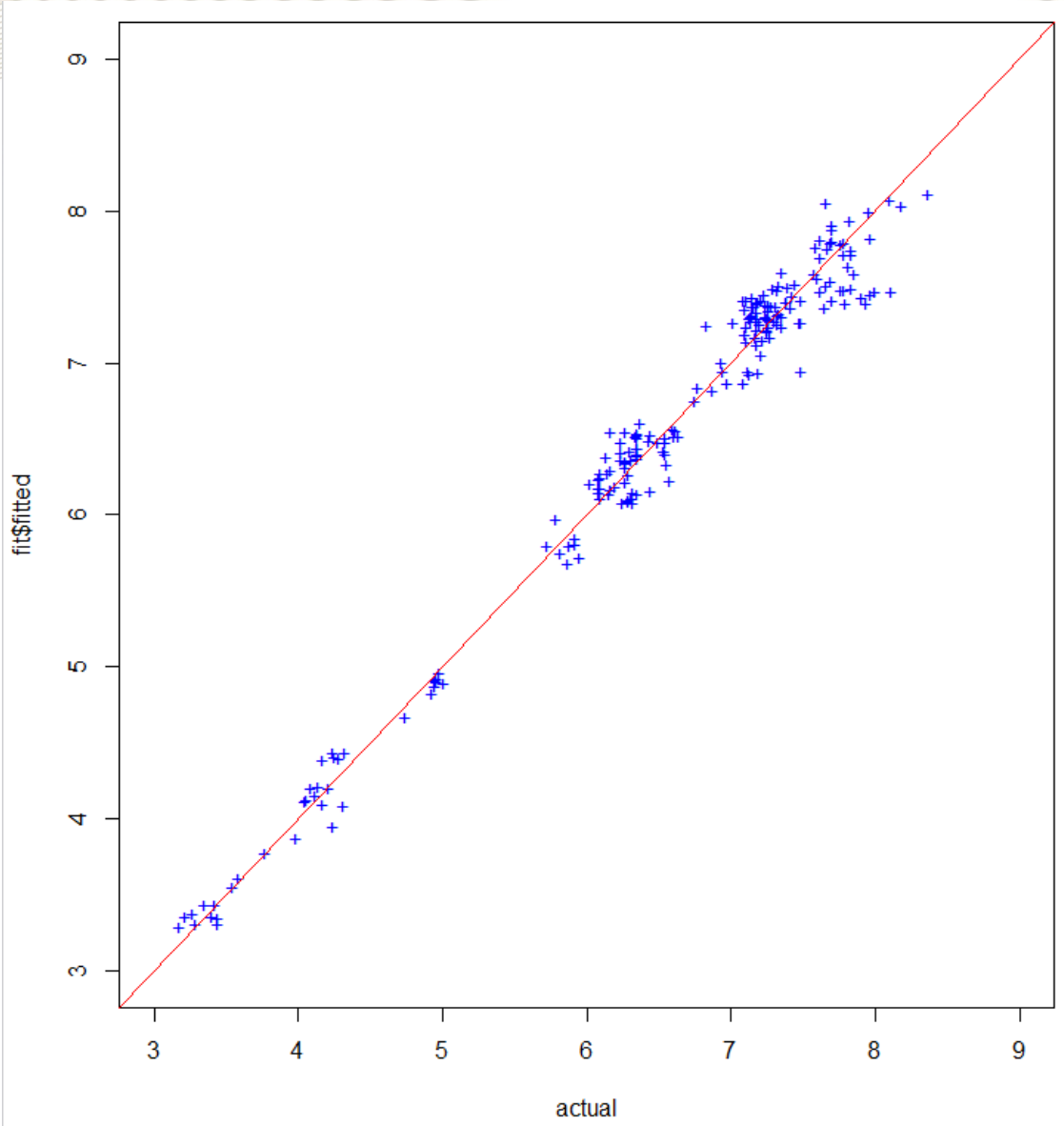
- M1 Abrams tank (2 blocks)
- M2 Bradley Fighting Vehicle (3 blocks)
- M9 Armored Combat Earthmover
- M998 HMMWV (2 blocks)
- M992 Field Artillery Ammunition and Support Vehicle (FAASV) (2 blocks)
- M4 Command and Control Vehicle (C2V)
- Stryker family (8 variants)
- M992A2 FAASV
- Armored Security Vehicle (ASV)
- Family of Heavy Tactical Vehicles (10 variants, ~2 blocks each)
- HMMWV (3 variants)
- MRAP variants
  - Buffalo
  - Cougar H
  - Cougar HE
  - MaxxPro
  - MaxxPro Dash
  - MaxxPro Dash DXM
  - MATV
  - MATV-UIK

IDA | Yearly Index Significance / Stability

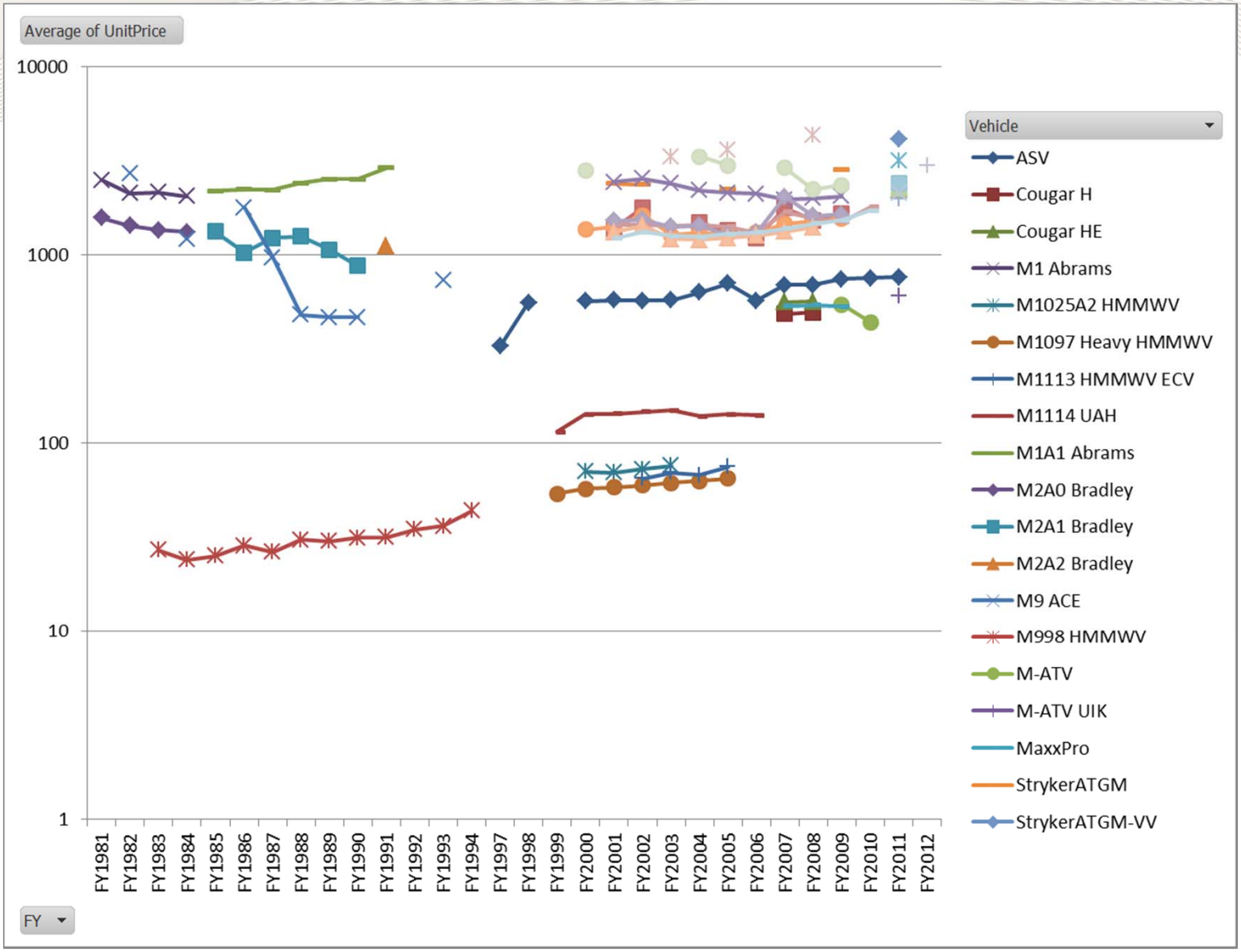
Ind1981	-1.19741	0.23820	-5.027	1.51e-06	***
Ind1982	-0.81351	0.22728	-3.579	0.000475	***
Ind1983	-1.33841	0.19836	-6.747	3.74e-10	***
Ind1984	-1.20171	0.20249	-5.935	2.23e-08	***
Ind1985	-1.30769	0.21043	-6.214	5.63e-09	***
Ind1986	-1.03952	0.19577	-5.310	4.24e-07	***
Ind1987	-1.11364	0.19268	-5.780	4.71e-08	***
Ind1988	-1.17351	0.18638	-6.296	3.74e-09	***
Ind1989	-1.23323	0.19112	-6.453	1.70e-09	***
Ind1990	-1.20646	0.18335	-6.580	8.87e-10	***
Ind1991	-1.21753	0.19325	-6.300	3.67e-09	***
Ind1992	-1.04304	0.25113	-4.153	5.69e-05	***
Ind1993	-1.01753	0.25062	-4.060	8.16e-05	***
Ind1994	-0.85338	0.24998	-3.414	0.000840	***
Ind1996	-0.74025	0.25731	-2.877	0.004650	**
Ind1997	-0.43995	0.21812	-2.017	0.045615	*
Ind1998	-0.61970	0.19555	-3.169	0.001882	**
Ind1999	-0.37114	0.17559	-2.114	0.036326	*
Ind2000	-0.11998	0.15745	-0.762	0.447349	
Ind2001	-0.10971	0.13765	-0.797	0.426786	
Ind2002	-0.07241	0.13645	-0.531	0.596487	
Ind2003	-0.11813	0.13609	-0.868	0.386871	
Ind2004	-0.01696	0.13884	-0.122	0.902974	
Ind2005	-0.04658	0.13319	-0.350	0.727042	
Ind2006	-0.10858	0.13772	-0.788	0.431821	
Ind2007	0.02043	0.12931	0.158	0.874663	
Ind2008	0.03024	0.12840	0.236	0.814165	
Ind2009	0.01292	0.13822	0.093	0.925669	
Ind2010	0.05820	0.14082	0.413	0.680008	



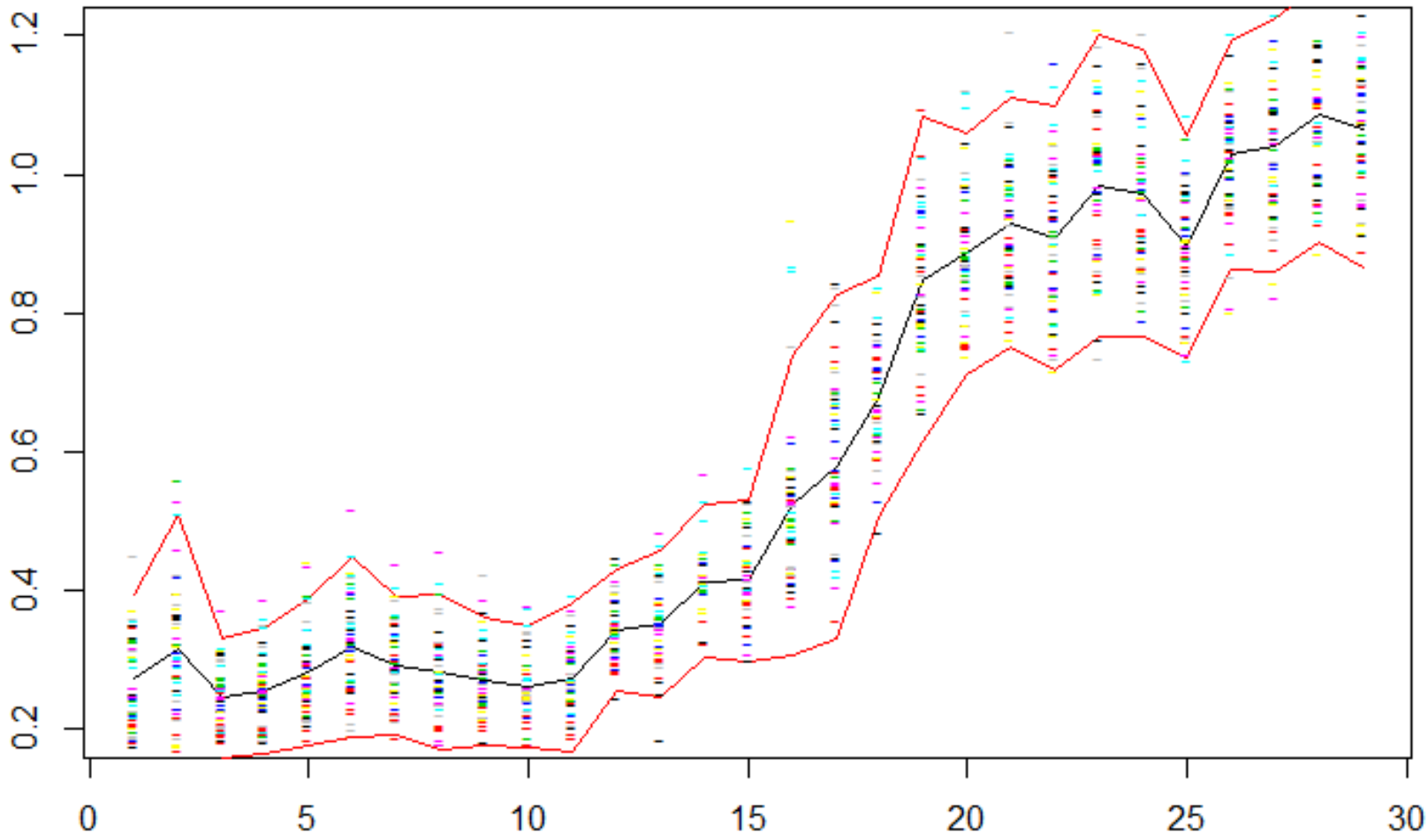
IDA | Predicted vs. Actual Log (Lot Price)



IDA | Negative Learning



IDA | High Standard Error for Annual Fixed Effects



Model Specification

$$\ln(U_j) = \beta_0 + \sum_{k=1}^{V} \beta_k I_{jk} + \sum_{k=1}^{V} \beta_{V+k} I_{jk} \ln(N_j) + \beta_{2V+1} \ln(Q_j) + \sum_{t=1}^{T} \alpha_t Y_{jt}$$

U_j = unit price of purchase j

V = number of vehicle types

Q_j = lot size of purchase j

N_j = lot number of purchase j

I_{jk} = $\mathbf{1}${ purchase j is of vehicle type k }

T = number of years covered by purchases

Y_{jt} = $\mathbf{1}${ purchase j was in year t }

Exp(α_t) = price index for year t

IDA | Way Forward

- Compile more data
  - Medium tactical vehicles
  - Fill the 1994–95 gap; extend beyond 2011
- Bootstrap to reduce the variance of the pure price model estimates as well
- Explore models with no lot size effect
  - Should an ideal price index describe price growth for fixed quality and quantity, or just quality?

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

When goods persist in the marketplace over time, price indices can be computed directly from observed prices. Hedonic models are used to estimate real price growth for goods that do not persist in the marketplace long enough to establish a price change history. Hedonic models attempt to explain as much price change as possible using observable quality features. We describe challenges in developing a hedonic price index for military vehicles, and propose an alternative pseudo-hedonic model based on hypothesized unobservable quality growth within in vehicle families.

15. SUBJECT TERMS

price index, hedonic, quality, military vehicle, bootstrap, regression

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