

# Manufacturer Certification in Second-Hand Markets

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# Motivation

- Cars change ownership several times over their life cycle
- In 2021, 15.3 million new cars and 43.1 million used cars were sold in the United States
- The global value of the used car market is expected to increase to USD 1.5 trillion by 2027
- Second-hand markets are characterised by quality uncertainty and adverse selection as sellers are better informed than buyers
- In 2022, the average used vehicle price at franchised dealers was GBP 7,800 higher than independent dealers in UK
- Manufacturer certification of second-hand goods has become a common practice in recent years
  - Sales of certified pre-owned cars have increased from 452,829 in 1997 to 2.75 million in 2021
  - Certified pre-owned cars sell for an average premium of \$1680

# Motivation

**Research Question:** If used goods are a competitor for new goods, why do manufacturers certify their quality?

- Quality certification reduces information asymmetry
  - It allows for price discrimination through better consumer segmentation
  - Certification increases the negative *substitution effect* but also improves the positive *resale value effect*
- We study the optimal choice of certification by manufacturers of durable goods to balance this trade-off

# Literature Review

## *Durable goods markets and adverse selection*

- Adverse selection: Akerlof (1970)
- Durable goods markets: Coase (1972); Sieper and Swan (1973); Anderson and Ginsburgh (1994); Waldman (1996)
- Durable goods markets with adverse selection: Hendel and Lizzeri (1999; 2002); Waldman and Johnson (2009); **Rao et al. (2009); Chen and Hsu (2017)**

## *Certification and adverse selection*

- Information disclosure: Peyrache and Quesada (2004); Lizzeri (1999)
- Sellers' investment in quality: Albano and Lizzeri (2001); Biglaiser and Li (2018); Bouvard and Levy (2018)

*Gap in literature:* Certification of used goods in the durable goods market by manufacturers

# Model

*Consumers* (Based on Rao et al. (2009))

- Consumers are infinitely-lived and discount the future by the factor of  $\delta \in (0,1)$
- Consumers own at most one good in each period
- They maximise discounted expected utility based on rational expectations about quality
- Consumer valuations for quality  $\theta$  are distributed uniformly on the interval  $[0,1]$
- For price  $p_t$  and quality  $q_t$ , their net utility from buying a good in period  $t$  is

$$U_t = \theta q_t - p_t$$

*Product*

- Each good lasts two periods (called new in first period, used in second)
- Quality of goods deteriorates over time

# Model

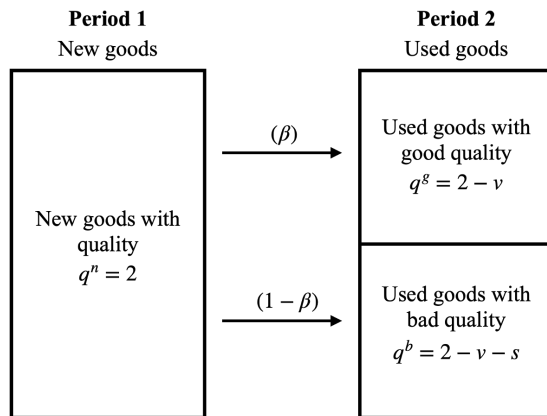


Figure: Quality deterioration from new to used goods

Assumptions:  $s > 0$ ,  $v > 0$ ,  $s + v < 2$  and  $0 < \beta < 1$

# Model

## *Manufacturer*

- Infinitely-lived profit-maximising monopolist with discount factor  $\delta \in (0, 1)$
- Produces  $y$  new goods each period at a constant marginal cost  $C_1$
- In the used goods market, it provides quality certification at a fee  $f$ 
  - The manufacturer incurs a cost  $C_2$  to test and certify each used good
  - It perfectly knows the quality of the used good after conducting the test
  - It only provides certification if the good has quality  $q^g$
- Firm maximises profits in each period:

$$\max_{y,f} \Pi = \max_{y,f} \{ (P^n - C_1)y + (f - C_2)n_c \}$$

where  $P^n$  is the price of new goods and  $n_c$  is the number of certified used goods

# Model

## *Information Asymmetry*

- All agents have perfect knowledge about the quality of new goods
- Sellers of used goods perfectly observe its quality ( $q^g$  or  $q^b$ )
- The manufacturer has perfect knowledge about the quality of used goods after testing
- Buyers observe whether the used good has certification and infer the quality
  - Certified used goods have quality  $q^g$
  - Non-certified used goods have quality  $q^b$

## *Timing of the game*

- First, the firm sets  $y$  and  $f$
- Then, consumers make decisions taking the tuple  $(v, s, \beta, P^n, P^c, P^u, f, y)$  as given
- New good prices  $P^n$ , certified used good prices  $P^c$  and non-certified used good prices  $P^u$  are determined by market clearing



# Certification Fee

## *Lemma*

Let  $f > 0$  and  $P^c - f > P^u$ . Then, in equilibrium,

1. A rational seller with a low quality used good never seeks certification.
2. A rational seller with a high quality used good always seeks certification.

# Consumer Behaviour

- Recall that consumers have unit demand
- In each period, a consumer can take one of the following actions:
  - Buy a new good
  - Keep a good from previous period
  - Buy a certified used good
  - Buy a non-certified used good
  - Not use
- With  $\theta$  and firm's problem constant over time, the game is stationary every two periods
- Five types of rational consumers emerge, based on patterns of behaviour in consecutive periods:
  - Compulsive buyers: acquire a new good in each period
  - Strategic holders: acquire a new good in period  $t$ ; keep if  $q^{\mathcal{E}}$  in period  $t+1$  and sell otherwise
  - Certified used good buyers: acquire a certified used good in each period
  - Non-certified used good buyers: acquire a non-certified used good in each period
  - Non-buyers: never buy

# Consumer Segments

Based on the vertical differentiation model (Mussa and Rosen, 1978), consumers self-select into the following segments:

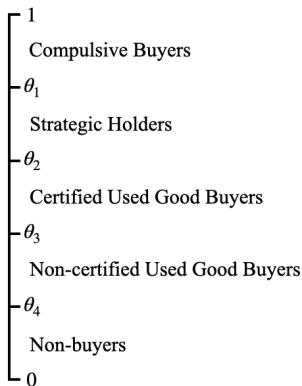


Figure: Consumer segments

## Discounted Expected Utility

The following equations represent the value functions for each type of consumer:

**Compulsive Buyers:**  $\theta \in [\theta_1, 1]$

$$V^n(\theta) = (\theta q^n - P^n) + \delta(\beta(P^c - f) + (1 - \beta)P^u + V^n(\theta))$$

**Strategic Holders:**  $\theta \in [\theta_2, \theta_1]$

$$V^s(\theta) = (\theta q^n - P^n) + \delta(\beta(\theta q^g + \delta V^s(\theta)) + (1 - \beta)(P^u + V^s(\theta)))$$

**Certified Used Good Buyers:**  $\theta \in [\theta_3, \theta_2]$

$$V^c(\theta) = (\theta q^g - P^c) + \delta V^c(\theta)$$

## Discounted Expected Utility

**Non-certified Used Good Buyers:**  $\theta \in [\theta_4, \theta_3]$

$$V^u(\theta) = (\theta q^b - P^u) + \delta V^u(\theta)$$

**Non-buyers** ( $\theta \in [0, \theta_4]$ ) get zero utility.

We calculate each segment size by finding the valuation ( $\theta$ ) for marginal consumers between types:

$$V^n(\theta_1) = V^s(\theta_1), V^s(\theta_2) = V^c(\theta_2), V^c(\theta_3) = V^u(\theta_3), V^u(\theta_4) = 0$$

[go back](#)

# Market Clearing

***New Goods Market:***

$$(1 - \theta_1) + \frac{1}{1 + \beta}(\theta_1 - \theta_2) = y$$

proof

***Certified Used Goods Market:***

$$(\theta_2 - \theta_3) = \beta(1 - \theta_1)$$

***Non-certified Used Goods Market:***

$$(\theta_3 - \theta_4) = (1 - \beta) \left( (1 - \theta_1) + \frac{1}{1 + \beta}(\theta_1 - \theta_2) \right)$$

go back

# Market Clearing

**Market clearing prices:**

$$P^n = \frac{2 + \delta(2 - v - s) + \beta(2 - f - \delta(v - 2 + \beta(f - s)))}{1 + \beta} - y(4 - v + 2\delta(2 - v) - s(1 - \beta)(1 + \delta(2 + \beta)))$$

$$P^c = 2 - v + y(s(1 - \beta) - 2(2 - v))$$

$$P^u = (2 - v - s)(1 - 2y)$$

[go back](#)

# Equilibrium

Using market clearing prices, we maximise the firm's objective function:

$$\max_{y,f} \Pi = \max_{y,f} \{(P^n - C_1)y + (f - C_2)n_c\}$$

where  $n_c = \theta_2 - \theta_3$  is the number of certified used goods.



## Summary of Results

- We compare the results of the model with certification to a **benchmark model** without certification
  - In the results, any variable  $x$  from the model without certification is referred to as  $\hat{x}$
- New goods supply  $y$  is lower in the model with certification than without
  - This reflects the *substitution effect* of certification
- Price of new goods  $P^n$  is higher in the model with certification than without
  - This reflects the *resale value effect* of certification
- The monopolist adjusts the fee of certification  $f$  to balance these opposing effects

# Model Calibration

- To illustrate the results, we calibrate the model using used and new car data from the US
- Following Biglaiser et al. (2020), we use price as an indicator of car quality
- In 2014, the average price of a high quality used car (sold by a dealer) was \$16,082 in Pennsylvania
- The average price of a low quality used car (sold privately) was \$7395 in Pennsylvania
- According to the Kelly Blue Book, the average price of a new car was \$32,160 in the US in 2014
- Normalizing the new good quality to  $q_n = 2$ , we set  $v = 1$  and  $s = 0.5$
- Dealer sales account for approximately 53% of used car sales; thus, we set  $\beta = 0.5$

# Consumer Segments

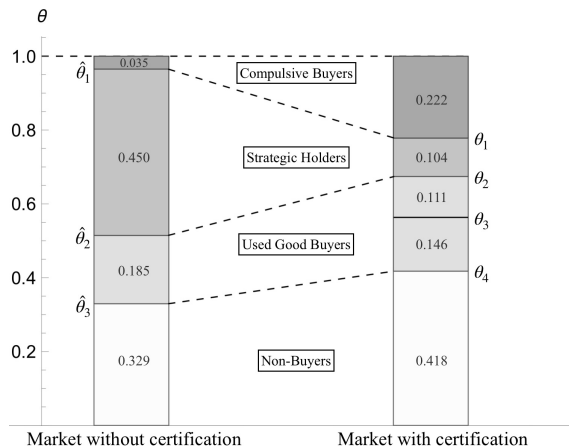


Figure: Effect of certification on consumer segments<sup>1</sup>

<sup>1</sup>All figures are constructed at the parameter values  $\beta = 0.5$ ,  $s = 0.5$ ,  $v = 1$ ,  $C_1 = 0.2$ ,  $C_2 = 0.1$  and  $\delta = 0.9$

# New Goods Supply and Certification Fees

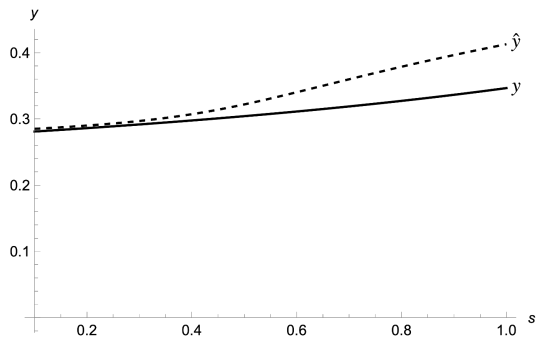


Figure: New goods supply

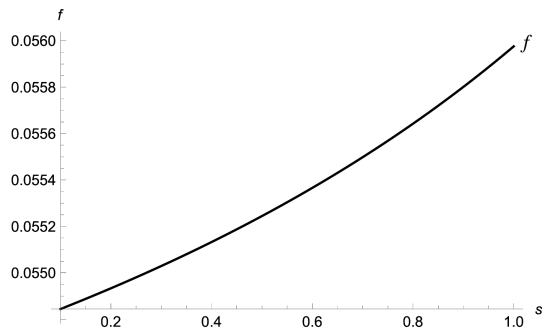


Figure: Certification fees

# Prices

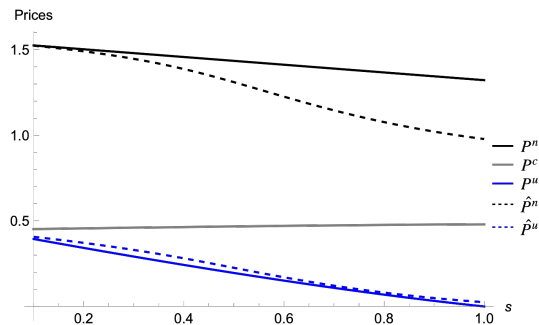


Figure: Prices in new and used goods markets

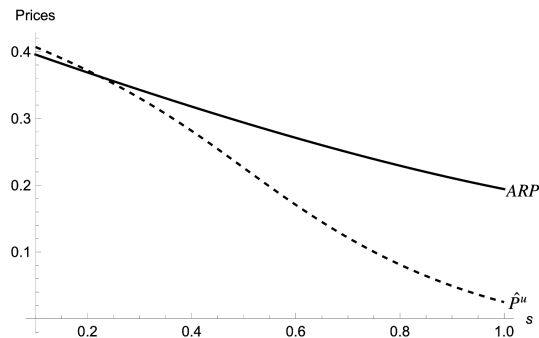


Figure: Average resale prices

→ The average resale price in the model with certification is

$$ARP = \frac{n_c(P^c - f) + n_u P^u}{n_c + n_u}$$

# Profits

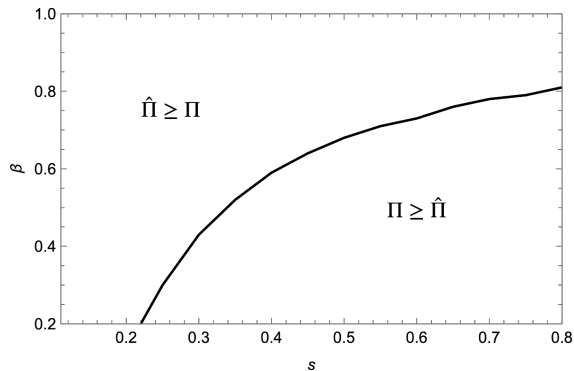


Figure: Profits for  $\nu = 1$

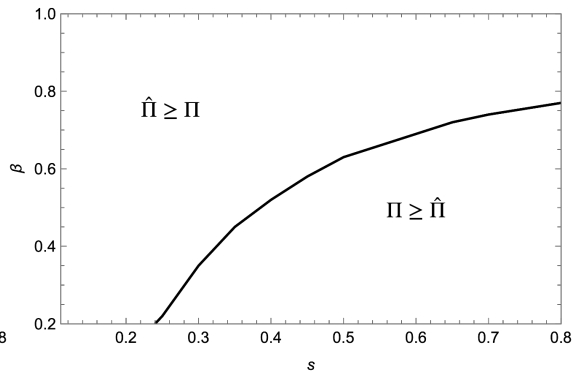


Figure: Profits for  $\nu = 1.2$

# Welfare and Consumer Surplus

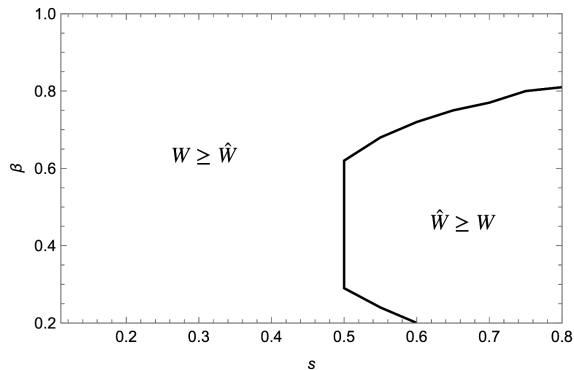


Figure: Welfare

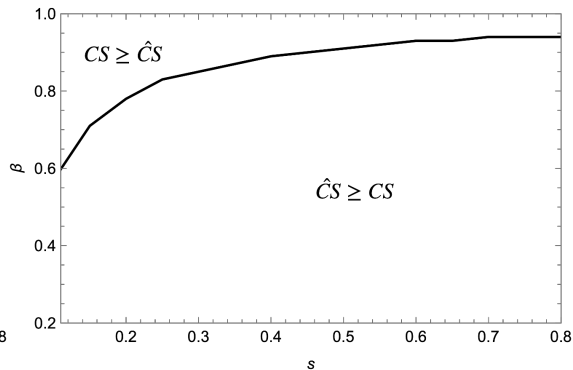


Figure: Consumer Surplus<sup>2</sup>

<sup>2</sup>These figures are constructed at the parameter values  $\nu = 1$ ,  $C_1 = 0.2$ ,  $C_2 = 0$  and  $\delta = 0.9$

# Profits from Certification

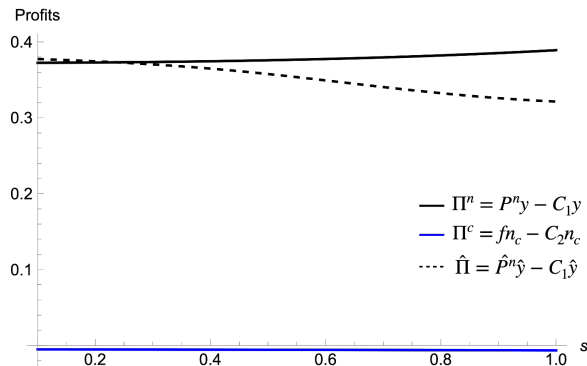


Figure: Profits from new goods market and certification

more results



# Conclusion

- The manufacturer does not completely solve the problem of adverse selection
  - The fee of certification encourages some owners to hold on to their high quality used goods
- The manufacturer mostly earns profits from certification through the resale value effect, instead of the fees charged
  - Third party certifiers charge a higher fee of certification
- As certification increases the price of new goods and reduces their supply, it is mostly detrimental for social welfare and consumer surplus

## Benchmark Model (Rao et al., 2009)

- The setup for consumers and product is unchanged
- Manufacturers do not interfere in the second-hand markets
  - They maximise the objective function:

$$\max_y \Pi = \max_y (P^n y - C_1 y)$$

- There are two types of goods in the market: New and Used
  - All agents have perfect knowledge about the quality of new goods
  - Sellers of used goods perfectly observe the quality
  - Buyers form rational expectations about the quality of used goods  $q^u$
- The timing of the game is unchanged
  - First, the firm sets  $y$
  - Then, consumers make decisions taking the tuple  $(v, s, \beta, P^n, P^u, y)$  as given
  - New good prices  $P^n$  and used good prices  $P^u$  are determined by market clearing

## Benchmark Model (Rao et al., 2009)

- There are four types of consumers in the steady state:

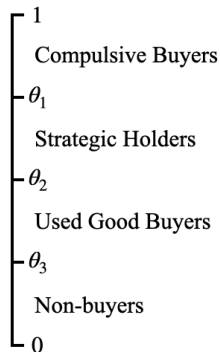


Figure: Consumer segments in the model without certification

- The analysis and solution follow the same steps as the model with certification

## Appendix

**Lemma:** The proportion of strategic holders, segment  $[\theta_2, \theta_1]$ , that demands new goods in any period is:

$$\frac{1}{1 + \beta}$$

**Proof:** Let  $x_t$  be the proportion of segment  $[\theta_2, \theta_1]$  consumers that demand new goods in period  $t$ . Then,  $(1 - x_t)$  comprises the proportion that keep their used goods in period  $t$ . In period  $t + 1$ , a proportion  $\beta$  of  $x_t$  will have good quality used goods and will hold on to their used goods. In a steady state, the proportion of the segment that holds their used goods must be the same in every period. Thus,

$$1 - x_t = \beta x_t \tag{1}$$

$$x_t = \frac{1}{1 + \beta} \tag{2}$$

## Effects of changes in $s$ , $v$ and $\beta$

### **Result 1**

Certification allows the monopolist to insulate its profits from changes in uncertainty in the quality of used goods, by partially separating the markets for high and low quality used goods. As  $s$  increases, the impact of certification on the markets increases.

### **Result 2**

The manufacturer benefits from certification when quality deterioration  $v$  is low. As  $v$  increases, the role of certification in durable goods markets diminishes as both the resale value and substitution effects of certification disappear.

### **Result 3**

The manufacturer benefits most from certification at intermediate values of  $\beta$ , where uncertainty is high. The monopolist chooses not to provide certification for high values of  $\beta$ .

## Effects of changes in $v$

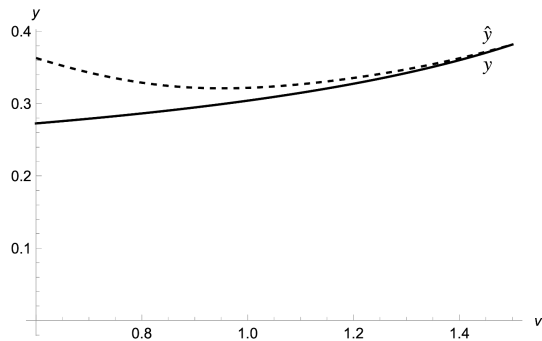


Figure: New goods supply

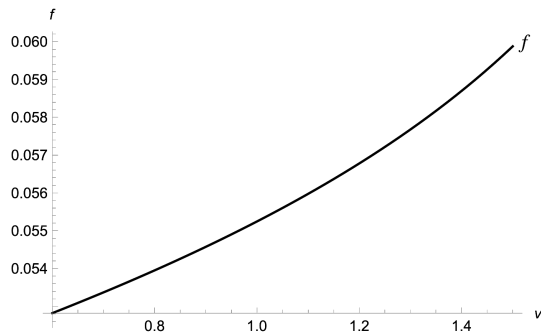


Figure: Certification fees

# Effects of changes in $v$

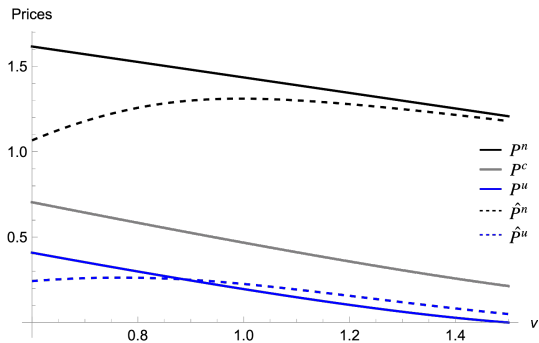


Figure: Prices in new and used goods markets

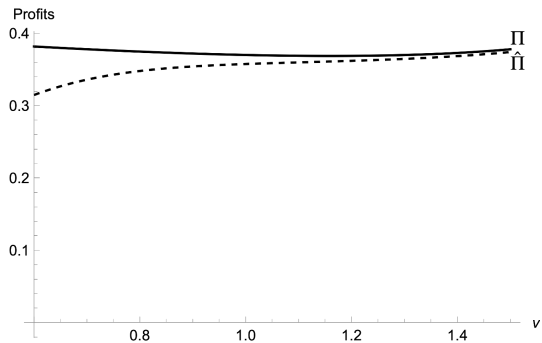


Figure: Profits in new and used goods markets

## Effects of changes in $\beta$

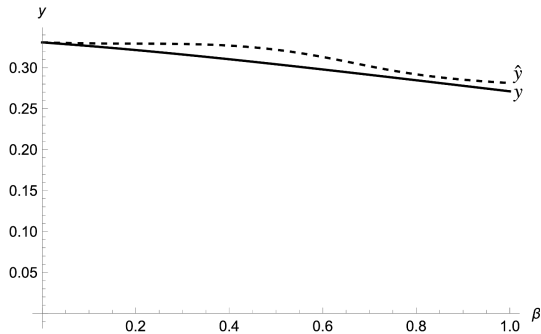


Figure: New goods supply

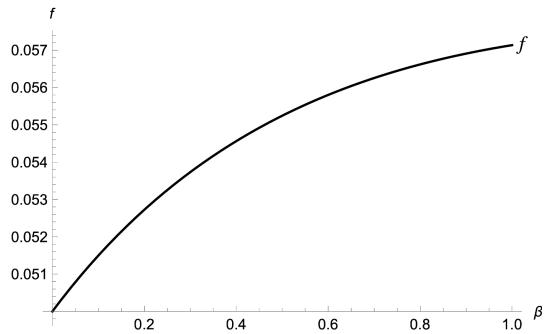


Figure: Certification fees



## Effects of changes in $\beta$

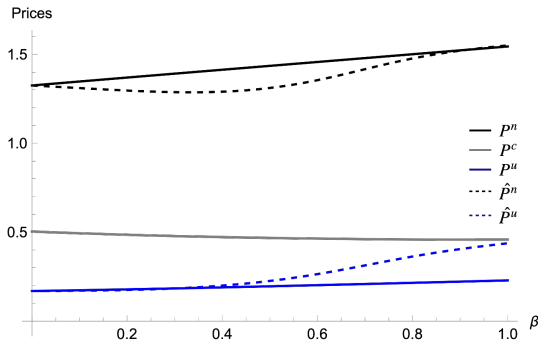


Figure: Prices in new and used goods markets

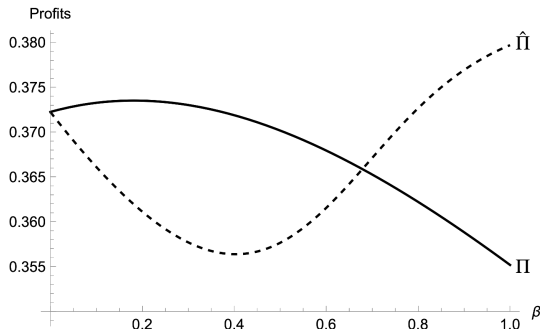


Figure: Profits in new and used goods markets