Tilburg University

On the incentives to provide fuel-efficient automobiles

Degryse, H.A.; Irmen, A.

Publication date:
1998

[Link to publication in Tilburg University Research Portal](#)

Citation for published version (APA):

Degryse, H. A., & Irmen, A. (1998). *On the incentives to provide fuel-efficient automobiles*. (CentER Discussion Paper; Vol. 1998-48). Finance.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

CBM
R
8414
1998
nr.48

entER
for
omic Research

Discussion paper

1008
98

Tilburg University

Center
for
Economic Research

No. 9848

**ON THE INCENTIVES TO PROVIDE FUEL-
EFFICIENT AUTOMOBILES**

By Hans Degryse and Andreas Irlen

May 1998

ISSN 0924-7815

On The Incentives to Provide Fuel-Efficient Automobiles

by

Hans DEGRYSE*, **

and

Andreas IRMEN**

CentER, Tilburg University, and CEPR

University of Mannheim

P.O. Box 90153

Fakultät für Volkswirtschaftslehre A5

NL-5000 LE TILBURG

D-68131 MANNHEIM

THE NETHERLANDS

GERMANY

Tel +31 13 4668210

e-mail:airmen@pool.uni-mannheim.de

Fax + 31 13 4662875

e-mail H.Degryse@kub.nl

Keywords: fuel-efficient automobiles, attributes, product differentiation.

* Corresponding author

** We are grateful to Miguel Rossellon Cifuentes and seminar participants at workshops in Lausanne, Tilburg and Mannheim. The first author acknowledges financial support from EC-Grant ERBFMBICT972240. The second author acknowledges money from the DFG Schwerpunktprogramm "Industriecoekonomik und Inputmaerkte".

Abstract

We argue that the provision of more fuel-efficient cars should be analyzed in the framework of a multi-dimensional product placement decision where attributes are dependent. This dependency arises because fuel-efficiency is linked to certain aerodynamic shapes. We show that the presence of this constraint may reduce the incentives to provide fuel-efficiency. In equilibrium cars become more similar and aerodynamic as fuel prices increase. However, the provided level of fuel-efficiency falls short of the social optimal one such that a minimum fuel economy standard is called for.

1. Introduction

Is the car industry willing to introduce more fuel-efficient vehicles? And if not, why? How will the car industry react if a fuel efficiency standard is imposed? These questions have become the subject of heated debate among the car industry and ecological organizations like Greenpeace. The focus is on the technological feasibility and marketability of a fuel efficient car (henceforth FEC) with a gas mileage of only 3 liters per hundred kilometers. The car industry claims that an FEC could already be supplied to the market but would be offered with less comfort at a higher price.¹ Greenpeace, however, has shown that these arguments are at best exaggerated. Greenpeace redesigned a Renault Twingo and thereby reduced its gas consumption from 5.6 to 3.2 liters per hundred kilometers without affecting neither comfort nor performance of the original model.

In this paper we claim that the car industry is reluctant to offer the FEC because the provision of higher fuel efficiency implies a modification of the attribute mix of their models which in turn may deteriorate their competitive position in the output market. Consider that an improvement of fuel efficiency can be achieved through more aerodynamic shapes, less weight, and better performing engines.²

¹See Albert Caspers, PDG Ford, and David J. Herman, PDG Opel, in *Wirtschaftswoche* (1995). Reduced comfort stems from the necessity that an FEC must be a lightweighted car. Potential buyers have to dispense with heavy equipment such as air-conditioning and/or steering aid (*Blick durch die Wirtschaft* (1996)).

²Greenpeace modified the Twingo at these three levels: first, they improved the aerodynamics by 30% changing the rear and front of the car. Second, they reduced the total weight by 20%

These means are linked to other product attributes such as size, styling, low noise and vibration highly valued by consumers.³ Moreover, high fuel economy itself is also one of these desirable vehicle attributes. Its provision should therefore not be seen as an end in itself but as a result of a product placement decision reflecting the different trade-off's between several dependent attributes. Hence, the FEC should result from an equilibrium attribute choice.

Our paper studies this argument in the framework of a simple two-dimensional product differentiation model. We consider competition between duopolistic car producers whose vehicles are vertically (quality) and horizontally (variety) differentiated. Vertical differentiation arises from the fact that all consumers prefer a more fuel efficient car if offered at the same price. Consumers differ in their preferences for the shape (styling) of a car. For instance, some prefer a 'three-box saloon' to a '5-door hatchback'. These differences in shape generate horizontal differentiation in the car market. In equilibrium firms have to determine a mix of the vertical and the horizontal attributes. The key observation is that these attributes are dependent, i.e., a high fuel efficiency can only be achieved if the car takes on a specific aerodynamic shape. The objective is then to derive the equilibrium mix of attributes and its comparative static properties.

making use of more lightweighted materials. Third, they redesigned the engine of the car (Le Journal de Geneve (1996)).

³Other attributes include acceleration and handling, safety, comfort, reliability, passenger- and load carrying capacity (see, National Research Council (1992), p. 30).

Aerodynamic drag is an important determinant for fuel economy. It is a force opposing the motion of a vehicle that results from the resistance of the ambient air to the movement of the vehicle through it.⁴ According to the National Research Council (1992) reductions of 20% in aerodynamic drag coefficients are possibly leading to an improvement of fuel economy of about 5%. Windtunnel tests show that there only exist certain optimal shapes minimizing gas consumption. Hence, firms are forced to approach these shapes when improving fuel efficiency through better aerodynamics. This dependency implies that cars become more and more similar whenever their fuel efficiency rises. Therefore, the variety of the cars' exterior decreases.⁵

We find that a technology constraint affects the willingness of car producers to provide fuel efficient cars. Furthermore, we show that car producers provide too little fuel efficiency. The intuition comes in two steps. First, a positive demand effect arises as increasing quality attracts consumers. This effect is stronger in the presence of a technology constraint since a higher quality implies less horizontal differentiation. As a result demand is more quality elastic in equilibrium. The

⁴"Fuel economy might be increased by redesigning the vehicle exterior to reduce the aerodynamic drag forces that consume a substantial proportion of the fuel energy at high speeds" (National Research Council (1992), p. 34). MacGready (1989) computes that the aerodynamic drag determines about 75% to 80% of the force to be overcome when driving a steady state cycle at 55-65 m.p.h..

⁵Similar trade-offs between quality characteristics may also be important for cars: a higher weight increases gas consumption but improves the road-behavior of a car; expanding the glass surface means better visibility and hence safety but increases the need for airconditioning which in turn increases weight thus gas consumption.

second force is strategic. Better aerodynamics imply a negative strategic effect. This effect is more pronounced in the presence of a technology constraint since the decrease in horizontal differentiation renders price competition fiercer thus inducing more aggressive price responses. Therefore, car producers underinvest in fuel efficiency in order not to induce an aggressive response by the competitor.

Our comparative static results suggest that when consumers care less about fuel economy, that is when real gasoline prices are low, the level of supplied fuel economy is also low. This reflects the situation in the US where gasoline is relatively inexpensive. The correlation between fuel prices and improvements in the fuel economy of cars has been observed by the National Research Council (1992), p. 13 – 16)) who states: “Between 1975 and 1991 the fuel economy of the average new car in the US improved by roughly 76 percent...The rate of improvement in fuel economy varied over the period. Significant gains were made during the early years...more modest gains were made from 1981 to 1988, and declines occurred from 1988 to 1991...The declining real price of gasoline since 1981 has discouraged further improvements”.

Clearly, a regulator should consider possible externalities fuel economy generates on motor vehicle emissions. This was one of the motivations of the U.S. Government to introduce Corporate Average Fuel Economy (CAFE) standards. A regulator should also incorporate potential costs due to the fact that a con-

sumer has to buy a vehicle with other attributes than he or she otherwise would have bought. In our model a minimum fuel economy standard is always beneficial. Since firms compete for the marginal consumer they underinvest in quality as this generates an aggressive response by the competitor. Our results also indicate that there is more need for fuel economy regulation when fuel prices are high.

In spite of the fact that products such as cars consist of several attributes, product placement decisions are usually analyzed in models of one-dimensional product differentiation. In these models all product attributes are summarized in a single parameter. It is just recently that the literature on product differentiation has taken up the topic of firms' product placement decisions in multi-dimensional product spaces.⁶ So far the major focus of this literature has been the study of the pure effect of competitive positioning along each dimension. This requires the assumption of attribute independence: firms can pick each attribute independently of the choice of other product characteristics. As we saw above this assumption may be unsatisfactory for some markets.

The literature closest to our study include papers which highlight different implications of attribute dependence such as Degryse (1996), Canoy and Peitz (1997), and Degryse and Irmen (1997). Degryse (1996) discusses attribute de-

⁶See, e.g., Economides (1989) and (1993), Neven and Thisse (1990), Hirlé et. al. (1990), Tabuchi (1994), Vandenbosch and Weinberg (1995), Ansari et. al. (1997), Irmen and Thisse (1998).

pendence between horizontal and vertical differentiation with an application to banking. In his paper banks face a discrete choice between a high and a low service quality. In contrast, this paper allows for a continuous quality choice. Canoy and Peitz (1997) support our conjecture that attribute dependence is an important phenomenon for the analysis of market structure. They start from the observation that submarkets for high-quality and low-quality are markedly different. In their model exogenously given variants in the low-quality range are identical for all consumers. Consumers strongly disagree about the value of variants in the high-quality segment. Hence, quality and variety are dependent but product attributes are exogenously given. In contrast, our paper endogenizes the attribute mix supplied by the firms. Degryse and Irmen (1997) study a model where attribute dependence arises indirectly since the quality offered by a firm determines the preference intensity consumers attach to its product. On the contrary, in this paper we model attribute dependence directly via a technology constraint.

The remainder of the paper is organized in the following way. Section 2 introduces the model. Section 3 solves for the non-cooperative equilibrium quality and section 4 discusses welfare considerations. Section 5 concludes.

2. The Model

In this section, we present a model of two-dimensional product differentiation which studies the trade-off of duopolistic car producers sketched out in the introduction. Cars can be vertically and horizontally differentiated. The vertical characteristic is a car's fuel consumption, the horizontal characteristic is its shape. The particularity of our model is that a low level of fuel consumption can only be provided if the automobiles approach a specific aerodynamic shape. In other words, a higher quality inevitably requires a variety closer to the competitor's product, thus reducing the degree of horizontal product differentiation in the market. This feature is introduced via a technology constraint.

Consider a market where two firms offer one product each. The product variants are characterized by a varietal and a quality characteristic, i.e., by the firms' location in $\mathbb{R}^2$. Firm A 's location is given by a vector (A, s_A) whereas firm B 's location is given by (B, s_B) . The capital letters A and B denote the firms' variety and s_A, s_B their respective quality.

There is a continuum of consumers distributed over the unit interval according to a uniform density function. Without loss of generality, we normalize the total population to 1. Each consumer is characterized by his most preferred product variety z . Consumers have a conditional indirect utility function $V_i(z)$, $i = A, B$. A consumer buying brand A enjoys a utility equal to (a similar expression holds

for a purchase of brand B)

$$V_A(z) = v + \theta s_A - p_A - (z - A)^2 \quad (2.1)$$

where

- v = gross surplus
- θ = marginal willingness to pay for quality
- s_A = quality of brand A
- p_A = firm A 's price
- z = the consumer's preferred variety
- A = variety provided by firm A

Consumers have unit demands. Furthermore, it is assumed that v is large enough for all consumers to buy at the price equilibrium corresponding to any location pair. The demand for variant A is then defined as the mass of consumers for whom variant (A, s_A) is weakly preferred to (B, s_B) , i.e., $V_A(z) \geq V_B(z)$.

Observe that $\theta \geq 0$ is the same for all consumers. This can be justified by pointing out that a quality improvement means a higher miles-per-gallon performance, hence savings in operational costs. Since cars have a given total lifetime mileage these savings will approximately be the same for each consumer.⁷

⁷This is true if we abstract from the facts that the lifetime mileage may be driven over differing time intervals, or that the car may be sold before the lifetime mileage has been reached.

Changes in θ can therefore be interpreted as reflecting fluctuations of the fuel price.⁸

Consumers disagree about their most preferred variety. This captures an important feature of the car market where consumers are known to differ with respect to their liking of brand specific designs. This aspect appears in the utility function of equation (2.1) as a standard quadratic transportation cost function with a per unit transportation rate normalized to equal 1.

In the next section we study how firms determine the level of fuel consumption in a symmetric equilibrium. The particularity of this decision is that a low level of fuel consumption can only be provided if the automobiles approach a specific aerodynamic shape. The question is then how to incorporate this feature in a symmetrical way into the model. Denote $\bar{s}$ the highest possible quality. It can be thought of as being the minimal amount of gas a car needs to cover a hundred kilometers. We assume that the aerodynamically optimal shape lies in the middle of the unit interval. In terms of consumer preferences this means that it corresponds to the median preference for variety. Furthermore, firm A is located to the left and firm B to the right of $1/2$. Hence, neither firm has an initial advantage of being closer to the optimal quality. The technological constraint

⁸Alternatively θ may proxy environmental concern of the population.

which links quality and variety is linear and given by

$$A = \gamma \cdot s_A$$

$$B = 1 - \gamma \cdot s_B.$$

The parameter γ is non negative such that an increase in quality shifts both varieties towards the center of the unit segment. It measures the units of horizontal differentiation firms have to give up for an additional unit of quality. Given this setup firm A can only improve s_A as long as $0 \leq A = \gamma \cdot s_A \leq 1/2$. Similarly, firm B can increase s_B only if $1/2 \leq B = 1 - \gamma \cdot s_B \leq 1$ holds. This introduces an upper bound on γ , i.e., $\gamma \leq 1/2s$.⁹

In order to capture the notion of quality we assume that at fixed prices no consumer is worse-off when the quality of either good improves, i.e., $\partial V_i(z) / \partial s_i \geq 0$ for all z and $i = A, B$. This introduces an upper bound on the interaction parameter and we obtain $0 \leq \gamma \leq \theta$. Hence, we have

$$0 \leq \gamma \leq \min \left\{ \frac{1}{2s}, \theta \right\}.$$

Production is such that the level of quality does not affect variable costs which

⁹Observe that the size of γ also determines the level of gas consumption that can be reached via aerodynamic optimization. Indeed, if γ is high an improvement in the aerodynamics is not a very efficient device to reduce fuel consumption. Thus, the size of γ differs for different segments of the car market.

are normalized to zero. However, there is a fixed cost associated with research and development of an aerodynamic design given by $C(s_i) = cs_i^2/2$. The quadratic form of the cost function reflects diminishing returns of investment in quality. This cost structure seems reasonable for the shape of cars since it is determined before production start. Hence, profit functions are

$$\pi_i(p_i, p_j, s_i, s_j) = p_i D_i(p_i, p_j, s_i, s_j) - C(s_i), \quad i, j = A, B, \quad i \neq j.$$

3. The Non-Cooperative Quality Game

In this section we study the symmetric subgame perfect equilibrium of the following two-stage game. At the first stage, firms choose the position of their variant in the product space $[0, 1] \times [0, \bar{s}]$. Due to the technology constraint the choice of quality determines implicitly the product's variety. Hence, the constrained product space is one-dimensional and firms choose $s_i \in [0, 1/2\gamma]$. At the second stage firms compete in prices. The two stage nature of the game reflects the fact that product characteristics such as the shape of a car and its associated fuel consumption are often less flexible than prices. Section 3.1 gives the solution to the second stage price game. The non-cooperative solution of the first stage quality game is presented in section 3.2.

3.1. The Price Game

Let consumers compare their preference for low gas consumption, the shape, and the price of the two cars available in the market. This trade-off gives rise to a marginal consumer location $\bar{z} \in [0, 1]$. Denote the horizontal distance between the two brands $\Delta \equiv B - A = 1 - \gamma(s_B + s_A)$. Then,

$$\bar{z} = \frac{p_B - p_A + \theta(s_A - s_B)}{2\Delta} + \frac{1 + \gamma(s_A - s_B)}{2}$$

which determines the firms' demand functions in a standard way. Explicitly, one obtains

$$D_A(p_A, p_B, s_A, s_B) = \begin{cases} 1 & \text{for } p_B - p_A \geq \Delta(1 + \gamma(s_B - s_A)) + \theta(s_B - s_A) \\ \bar{z} & \text{for } \Delta(1 + \gamma(s_B - s_A)) + \theta(s_B - s_A) \geq p_B - p_A \\ & \geq \theta(s_B - s_A) - \Delta(1 + \gamma(s_B + s_A)) \\ 0 & \text{for } \theta(s_B - s_A) - \Delta(1 + \gamma(s_B + s_A)) \geq p_B - p_A. \end{cases}$$

Firm B 's demand is implicitly given as $D_B = 1 - D_A$.

We can already get a first understanding of how γ affects the outcome of the game by analyzing its impact on demand. We have

$$\left| \frac{\partial^2 D_i(\cdot)}{\partial p_i \partial \gamma} \right| \geq 0,$$

and for symmetric locations and prices one can show that

$$\left. \frac{\partial^2 D_i(\cdot)}{\partial s_i \partial \gamma} \right|_{s_A=s_B, p_A=p_B} \geq 0, \quad i = A, B.$$

Hence, in the neighborhood of a symmetric outcome more consumers switch brands in response to a change in price or quality as γ increases. This has the following implications. On the one hand, the provision of a higher quality becomes more attractive because its positive impact on demand is more pronounced. On the other hand, for given qualities demand becomes more price elastic which implies lower prices at equilibrium. The question is then which of the two opposing effects dominates at the equilibrium. In order to get the complete picture we first have to study the price equilibrium in more detail.

Straightforward computations yield the price equilibrium as

$$p_A^* = \Delta \left[1 + \frac{\gamma}{3} (s_A - s_B) \right] + \frac{\theta}{3} (s_A - s_B), \quad (3.1)$$

$$p_B^* = \Delta \left[1 + \frac{\gamma}{3} (s_B - s_A) \right] + \frac{\theta}{3} (s_B - s_A). \quad (3.2)$$

Three remarks are in order. First, observe that the equilibrium price consists of two components. The first component reflects the degree of horizontal product differentiation.¹⁰ It depends on the interaction parameter γ as well as on the

¹⁰The first term of (3.1) can actually be written as $\Delta (2 + B + A) / 3$ whereas the first term of

provided quality levels. The second component shows the pure effect of vertical differentiation. It is the more pronounced the higher the consumers' willingness to pay for a quality improvement, and the more products are differentiated with respect to quality.

Second, as expected we have

$$\partial p_i^* / \partial \gamma \leq 0, i = A, B.$$

Hence, price competition becomes tougher as γ increases. For a given level of quality firms locations on the line move closer thus intensifying price competition along the varietal characteristic. Accordingly, at the price equilibrium demand functions become more price elastic.

Third, unlike standard models of quality choice a quality improvement of one's product does not necessarily allow for a higher price in equilibrium. In fact, we have

$$\frac{dp_i^*}{ds_i} = \frac{\theta - 2\gamma(1 + \gamma s_i)}{3} < 0 \text{ if } \gamma > \bar{\gamma} = \frac{\sqrt{1 + 2s_i} - \theta}{2s_i}, i = A, B.$$

The reason is the following. It is easy to show that for all admissible values of γ an increase in s_i shifts firm i 's best reply outward. This allows for a higher p_i^* in spite of the fact that firm j 's best reply shifts inwards as s_i augments as long as

(3.2) is equal to $\Delta(4 - B - A)/3$. Both expressions coincide with the equilibrium prices of the standard Hotelling model with quadratic transportation costs (see, d'Aspremont et al. (1979)).

γ is sufficiently low. If $\gamma > \bar{\gamma}$ a higher quality implies an inward shift of j 's best reply at least twice as big as the outward shift of i 's best reply. Thus, horizontal differentiation decreases to such an extent that the ensuing intensification of price competition along this characteristic requires p_i^* to fall in equilibrium. It is then interesting to study how the technology constraint affects firms' choice of quality at the first stage of the game.

3.2. The Quality Game

Evaluated at the price equilibrium the marginal consumer location $\bar{z}$ is given by

$$\bar{z} = \frac{\theta(s_A - s_B) + \Delta(3 + \gamma(s_A - s_B))}{6\Delta},$$

such that Firm A 's demand function becomes

$$D_A(s_A, s_B) = \begin{cases} 1 & \text{for } s_A - s_B \geq \Delta[3 - \gamma(s_A - s_B)]/\theta \\ \bar{z} & \text{for } \Delta[3 - \gamma(s_A - s_B)]/\theta \geq s_A - s_B \\ & \geq -\Delta[3 + \gamma(s_A - s_B)]/\theta \\ 0 & \text{for } -\Delta[3 + \gamma(s_A - s_B)]/\theta \geq s_A - s_B \end{cases} \quad (3.3)$$

Again, demand for firm B equals $1 - D_A$. Firms maximize profits

$$\pi_A = \frac{[\theta(s_A - s_B) + \Delta(3 + \gamma(s_A - s_B))]^2}{18\Delta} - \frac{c}{2}s_A^2$$

$$\pi_B = \frac{[\theta(s_B - s_A) + \Delta(3 + \gamma(s_A - s_B))]^2}{18\Delta} - \frac{c}{2}s_B^2$$

simultaneously w.r.t. their quality on $s_i \in [0, \bar{s}]$, $i = A, B$ where $\bar{s} \leq 1/2\gamma$. This leads to an overall equilibrium characterized in Proposition 1.

Proposition 1. *There exists a unique symmetric equilibrium in pure strategies if $c \geq \bar{c} = 2\theta^2/3\sqrt{3}$. The equilibrium quality is given by*

$$s^{nc} = \max \left\{ 0, \frac{2\theta - \gamma}{2(3c + 2\gamma^2)} \right\}$$

while equilibrium prices are $p^{nc} = \Delta$.

Proof: See Appendix.

Proposition 1 shows that the equilibrium quality offered depends on θ and γ . Observe that quality increases in θ . During times of increasing fuel prices and/or higher environmental concern, the model predicts more similar and aerodynamic cars with lower gas consumption. Casual empiricism confirms this prediction. Furthermore, the provision of quality requires that the consumers marginal willingness to pay for quality is sufficiently high, i.e. $\theta > \gamma/2$.¹¹

¹¹Notice that the latter is always satisfied in our model since the notion of quality implies that $\theta \geq \gamma$. The second case where no quality is provided is the one where c is so high that firms would make losses at any $s > 0$.

More importantly, we have

$$\frac{ds^{nc}}{d\gamma} = -\frac{3c + 2\gamma(4\theta - \gamma)}{2(3c + 2\gamma^2)^2} < 0. \quad (3.4)$$

i.e., the equilibrium quality unequivocally falls as γ increases. The intuition comes from the first order condition of the quality game, which is

$$\frac{d\pi_i(s_i, s_j)}{ds_i} = p_i \left[\frac{\partial D_i}{\partial s_i} + \frac{\partial D_i}{\partial p_j} \frac{dp_j}{ds_i} \right] - cs_i = 0, \quad i, j = A, B; i \neq j \quad (3.5)$$

Evaluation of p_i at the second stage equilibrium and using the fact that $\partial D_i / \partial p_i + \partial D_i / \partial p_j = 0$ allows us to rewrite (3.5) as

$$D_i \left[\frac{dp_i}{ds_i} \Big|_{D_i=const.} + \frac{dp_j}{ds_i} \right] = cs_i, \quad (3.6)$$

where the first term in square brackets measures by how much firm i can increase its price in response to a marginal increase in quality while keeping its demand constant. The second term is the rival's price reaction to such a marginal increase.

Intuitively, changes in s_i and p_i can only be “demand neutral” if they leave the position of the marginal consumer unaffected. Hence, in equilibrium the first term must be such that it leaves the indirect utility of the marginal consumer unchanged. Since a symmetric equilibrium requires a 50 : 50 split of demand we have $\bar{z} = 1/2$ and obtain the value of $dp_i/ds_i|_{D_i=1/2}$ from totally differentiating

the indirect utility (2.1) at $z = 1/2$, which is

$$\left. \frac{dp_i}{ds_i} \right|_{D_i=1/2} = \theta + \gamma\Delta. \quad (3.7)$$

Hence, the marginal consumer's marginal willingness to pay for a quality improvement reflects his marginal willingness to pay for quality and the reduction in transportation costs associated with an inward shift of the firms' varieties.¹²

The second term in (3.6) is determined from (3.1) or (3.2) and after imposing symmetry equal to¹³

$$\frac{dp_j}{ds_i} = -\frac{1}{3} [\theta + \gamma(3 + \Delta)]. \quad (3.8)$$

Quality is an aggressive decision variable since the rival reacts to a marginal increase with a price reduction. His reaction is stronger the higher γ , i.e., the tougher price competition is. Overall, it is easily seen that the negative effect an increase in γ has on the strategic term more than outweighs any positive impact it can have on the marginal consumer's marginal willingness to pay. Thus, such an increase reduces the LHS of (3.6) which establishes the comparative static result stated in (3.4).

Equilibrium prices are equal to the horizontal distance of firms. Products are homogeneous with respect to quality so that the latter has no direct effect on

¹²Observe that $g(\gamma) = \gamma\Delta$ is a hyperbola with $\arg \max_{\gamma} = 1/4$.

¹³Of course, insertion of (3.7) and (3.8) in (3.6) gives s^{nc} of proposition 1.

prices. However, due to the technological constraint prices depend indirectly on quality. Since a higher quality implies less horizontal differentiation prices fall as quality increases. In particular unlike what is usually found equilibrium prices fall in the consumers' marginal willingness to pay for quality, i.e.

$$\frac{dp^{nc}}{d\theta} \leq 0.$$

Observe furthermore that

$$\frac{dp^{nc}}{d\gamma} = \frac{2[3c(\theta - \gamma) - 2\theta\gamma^2]}{(3c + 2\gamma^2)}.$$

The sign of $dp^{nc}/d\gamma$ depends on θ and c . It is easily verified that

$$\frac{dp^{nc}}{d\gamma} < 0 \text{ iff } \gamma < \hat{\gamma} = \frac{-3c + \sqrt{3c(8\theta + 3c)}}{4\theta} \quad (3.9)$$

i.e., when c and θ are high the equilibrium price is likely to fall in γ . This is the result of two opposing effects, i.e.

$$\frac{dp^{nc}}{d\gamma} = \frac{\partial p^{nc}}{\partial \gamma} \bigg|_{s=s^{nc}} + \frac{\partial p^{nc}}{\partial s} \frac{ds^{nc}}{d\gamma}.$$

$(-)$ $(-)$ $(-)$

First, there is a direct price competition effect which is negative. Leaving quality unchanged, an increase in γ decreases horizontal differentiation on the line. Price

competition is more intense thus p^{nc} must fall. Second, there is an indirect effect since firms adapt s^{nc} to changes in γ . From equation (3.4) we know that the equilibrium quality falls in γ . Hence, the distance between the goods augments and prices can rise.¹⁴

4. Optimal Quality Standard

In this subsection, we discuss the behavior of a regulator maximizing social welfare by imposing a quality standard s^{sw} . The welfare measure we use is a simple addition of consumer and producer surplus. Furthermore we include a term capturing possible externalities fuel economy generates on motor vehicle emissions.

The consumer surplus CS boils down to

$$CS = v + \theta s - (1 - 2\gamma s) - 2 \int_0^{1/2} (\gamma s - z)^2 dz.$$

The first term is the gross surplus each consumer enjoys from purchasing one unit of the good. The second component measures the consumers' utility derived from quality s . The last two terms are the price customers pay and the average

¹⁴One might also be interested in the case of semi-collusion where the duopolists coordinate their quality decision but compete in prices (R&D cartel). However, since aggregate demand is constant and quality an aggressive variable no quality will be provided in equilibrium. The intuition is that, apart from costs, the cartel members only care about the impact of quality on own and rival's prices. Since price competition becomes tougher for non negative γ firms are better off if $s = 0$ (see, Degryse and Irmen (1997), p. 15).

transportation cost a customer incurs when purchasing either brand.

The producer surplus PS consists of two components and equals

$$PS = [1 - 2\gamma s] - c(s)^2.$$

The term in brackets represents total revenues whereas the second is the cost of developing the quality level s .

The possible (positive) externalities fuel economy generates on motor vehicle emissions and hence the environmental quality, is represented by αs , $\alpha \geq 0$.¹⁵ For simplicity, we assume the effect of quality, i.e. fuel economy, is proportional to the damage of motor vehicle emissions on environmental quality.

Adding consumer surplus CS , producer surplus PS and the externality term gives an expression for total welfare denoted TW

$$TW = CS + PS + \alpha s = v + \theta s - 2 \int_0^{1/2} (\gamma s - z)^2 dz - c(s)^2 + \alpha s.$$

Notice that TW does not reflect revenues since they constitute a pure redistribution between producers and customers. A higher quality standard has then four

¹⁵The evidence concerning the relation between fuel economy and motor vehicle emission is mixed. Khazzoom (1995) finds for new cars that increased fuel economy leaves the emission rate unchanged. Harrington (1997) also takes the aging of cars into account. His findings show that a better fuel economy is strongly associated with lower emission rates. Furthermore, when fuel economy improves, the marginal cost of travel declines, and the demand for travel goes up, potentially contributing to a degradation of air quality.

effects. First, it positively affects the indirect utility of the customers. Second, it changes the total amount of transportation costs customers face, as they cannot buy their most preferred shape. Third, it increases the development costs $c(s)^2$. Finally, a higher quality standard generates externalities on the motor vehicle emissions.

The optimal quality standard s^{sw} is given in Proposition 2.

Proposition 2. *Assume that costs are such that the non-cooperative quality equilibrium exists. Then the optimal quality standard s^{sw} chosen by a regulator is*

$$s^{sw} = \min \left\{ \frac{\sqrt{c + \gamma^2} - \gamma}{c}, \frac{2(\theta + \alpha) + \gamma}{4(c + \gamma^2)} \right\}.$$

We obtain $p^{sw} = 1 - 2\gamma s^{sw}$ as equilibrium prices and $s^{sw} > s^{nc}$ for all $\alpha \geq 0$.

Proof: We have to maximize TW w.r.t. s under the following constraints:

1. non-negativity of PS : $s \leq (\sqrt{c + \gamma^2} - \gamma) / c$
2. technology constraint: $s \leq 1/2\gamma$

It is then easily verified that the first constraint binds earlier than the last constraint. The first constraint is binding if

$$c \geq \hat{c} = \left[4(\theta + \alpha)^2 + 20\gamma(\theta + \alpha) - 23\gamma^2 + \sqrt{(2(\theta + \alpha) + \gamma)^3(2(\theta + \alpha) + 17\gamma)} \right] / 32.$$

The second derivative is always negative. Q.E.D.

Observe that the optimal quality standard depends on θ and the interaction parameter γ . More importantly, we find that $s^{sw} > s^{nc}$ for all admissible parameter values. However s^{sw} does not necessarily increase in γ . The reason is that γs^{sw} determines the location of the brands in the unit interval and thus the level of total transportation costs. For low levels of γ , a higher quality also reduces aggregate transportation costs. That is, on average consumers like more the aerodynamic styling. Accordingly, s^{sw} increases in γ . If γ gets larger this force disappears and lower levels of s^{sw} become socially desirable. In other words, the styling of cars becomes too aerodynamic.¹⁶

The optimal quality standard increases whenever fuel economy improves environmental quality. The reason is that a regulator has extra incentives to ask for higher fuel economy since this generates positive externalities. Hence, the difference between the socially optimal quality standard s^{sw} and the market determined fuel economy s^{nc} increases. Thus, a minimum fuel economy standard is called for.

Alternative policies to improve fuel economy are possible. One policy often

¹⁶More precisely, one can show analytically that

$$\frac{\partial s^{sw}}{\partial \gamma} = - \frac{\overbrace{\frac{\partial^2 TR}{\partial s \partial \gamma}}^{(+/-)}}{\underbrace{\frac{\partial^2 c(s)^2}{\partial s^2} + \frac{\partial^2 TR}{\partial s^2}}_{(-)}}$$

where TR denotes aggregate transportation costs.

used in practice is to impose excise taxes designed to increase fuel prices. The idea is to have fuel prices reflect the ‘true cost of fuel use.’ In our model, this policy increases θ since a higher fuel price augments consumers’ savings due to a better gas mileage. Accordingly, firms provide a higher quality s^{nc} . However, the gap between s^{sw} and s^{nc} widens.¹⁷

5. Concluding Remarks

The discussion about the incentives to provide fuel-efficient cars is likely to remain intense since real fuel prices are high and environmental concern growing. Our paper points to an argument that, among others, helps to explain the reluctant attitude of the car industry to supply the market with the FEC.

We understand the provision of a particular product attribute as part of a multi-dimensional decision problem. The resulting equilibrium set of attributes reflects demand and strategic considerations. Furthermore, we argue that firms may face a constrained product space and show that a technological constraint may imply disincentives to provide quality.

Our results highlight that the shapes of cars become more similar and aerodynamic as consumers’ marginal willingness to pay for a better gas mileage increases.

¹⁷Other policies to influence fuel economy are fees for consumers buying a below average fuel economy and rebates for those buying above average fuel economy cars (see also National Research Council (1992, p.179).

In spite of this the market determined level of fuel efficiency falls short of the social optimal one which supports the imposition of fuel economy standards like CAFE.

References

- [1] Ansari, A., Economides, N., Steckel, J., (1997), The Max-Min Principle of Product Differentiation, *Journal of Regional Science*, forthcoming
- [2] d'Aspremont, C., Gabszewicz, J.J., Thisse, J.-F., (1979), On Hotelling's 'Stability in Competition', *Econometrica*, vol. 47, pp. 1145-1150
- [3] Blick durch die Wirtschaft, (1996, February 26), *Das kraftstoffarme Automobil kann kein billiges Fahrzeug werden*, by Jochen Seyboth
- [4] Canoy, M., Peitz, M., (1997), The Differentiation Triangle, *Journal of Industrial Economics*, vol. 45, pp. 305-328
- [5] Degryse, H., (1996), On the Interaction between Horizontal and Vertical Product Differentiation: An Application to Banking, *Journal of Industrial Economics*, vol. 44, pp. 169-186

- [6] Degryse, H., Irmen, A., (1997), Attribute Dependence and the Provision of Quality, *CEPR Discussion Paper*, No. 1635

- [7] Economides, N., (1989), Quality Variations and Maximal Variety Variation, *Regional Science and Urban Economics*, vol. 19, pp. 21–29

- [8] Economides, N., (1993), Quality Variations in the Circular Model of Variety-Differentiated Products, *Regional Science and Urban Economics*, vol. 23, pp. 235–257

- [9] Harrington, W., (1997), Fuel Economy and Motor Vehicle Emissions, *Journal of Environmental Economics and Management*, vol. 33, pp. 240–252

- [10] Hirlé, L., Lerch, C., Matt, M., (1990), *Un modèle de concurrence mixte et son extension*, Master Thesis, Department of Economics, Université Louis Pasteur de Strasbourg

- [11] Irmen, A., Thisse, J.-F., (1998), Competition in Multi-characteristics Spaces: Hotelling was Almost Right, *Journal of Economic Theory*, forth-

coming

- [12] **Khazzoom, J. D., (1995)**, An Econometric Model of the Regulated Emissions for Fuel-Efficient New Vehicles, *Journal of Environmental Economics and Management*, vol. 28, pp. 190–204
- [13] **Le Journal de Genève, (1996, August 8)**, *Trois litres au cent. Greenpeace présente sa Twingo écolo*
- [14] **MacGready, P.B., (1989)**, Perspectives in Transportation, *Journal of the Airpollution Control Association*, pp. 1428–1429
- [15] **National Research Council, (1992)**, *Automotive Fuel Economy: How far should we go?*, Washington DC, National Academic Press
- [16] **Neven, D., Thisse, J.-F., (1990)**, On Quality and Variety Competition, in J.J. Gabszewicz, J.-F. Richard, and L.Wolsey (eds.), *Economic Decision Making: Games, Econometrics, and Optimization*. Contributions in the Honour of Jacques H. Drèze, Amsterdam: North-Holland, pp. 175–199
- [17] **Tabuchi, T. (1994)**, Two-Stage Two-Dimensional Spatial Competition between Two Firms, *Regional Science and Urban Economics*, vol. 24, pp. 207–227

- [18] Vandenbosch, M.B., Weinberg, C.B. (1995), Product and Price Competition in Two-Dimensional Vertical Differentiation Model, *Marketing Science*, vol. 14, pp. 224–249
- [19] **Wirtschaftswoche**, (1995, September 5), *Säuft nicht, läuft nicht*, by Franz W. Rother

6. Appendix

Proof of Proposition 1:

We proceed as follows. First, we solve for the symmetric equilibrium in quality and develop a condition on c under which the profit functions attain a maximum at this equilibrium. Second, we show that under this condition there is no profitable deviation in the strategy space. We deal explicitly with firm A . By symmetry, the same result holds for firm B .

1. Firm A's profit at the price equilibrium is of the form

$$\pi_A(s_A, s_B) = p_A(s_A, s_B) D_A(p_A(s_A, s_B), p_B(s_A, s_B), s_A, s_B) - C(s_A).$$

Deriving with respect to s_A and imposing symmetry yields the equilibrium quality as $s^{nc} = \max\{0, (2\theta - \gamma) / [2(3c + 2\gamma^2)]\}$. The second order condition requires that

$$\left. \frac{\partial^2 \pi_A}{\partial s_A^2} \right|_{s_A=s_B=s^{nc}} = \theta \left[\frac{2\gamma}{9} + \frac{\theta}{9\Delta} \right] - \frac{\gamma^2(5 + 2\gamma s)}{9} - c \leq 0. \quad (6.1)$$

Condition (6.1) is satisfied for all admissible values of γ if $c \geq 2\theta^2/3\sqrt{3}$.

2. We show that firm A cannot increase its profit by choosing

$s_A \neq s^{nc}$ on $s_A \in [0, 1/2\gamma]$ given that $s_B = s^{nc}$.¹⁸ The proof of this second part will proceed as follows. We first discuss where a profitable deviation from the equilibrium can occur. Next, we establish conditions under which no such profitable deviation exists.

Observe that

$$\frac{\partial^3 \pi_A}{\partial s_A^3} = \frac{\gamma \theta^2 (1 - 2\gamma s_B)^2}{3\Delta^4} - \frac{\gamma^3}{3}$$

and

$$\frac{\partial^4 \pi_A}{\partial s_A^4} = \frac{4\gamma^2 \theta^2 (1 - 2s_B)^2}{3\Delta^5} > 0.$$

Notice that $\partial^3 \pi_A / \partial s_A^3|_{s_A=s_B=s^{nc}} > 0$ since $\theta \geq \gamma$. We have to consider two possibly profitable deviations one to the right and the other to the left.

First, consider deviations to the right, i.e., $s_A > s^{nc}$. Since $\partial^4 \pi_A / \partial s_A^4 > 0$, we have $\partial^3 \pi_A / \partial s_A^3 > 0$ for $s_A > s^{nc}$. Accordingly, $\partial \pi_A / \partial s_A$ is strictly convex in s_A on $[s^{nc}, 1/2\gamma]$. Since $\partial^2 \pi_A / \partial s_A^2|_{s_A=s_B=s^{nc}} < 0$ the most profitable deviation, if it exists, arises at $s_A = 1/2\gamma > s^{nc}$.

Second, consider deviations to the left, i.e., $s_A < s^{nc}$. The fact that the fourth derivative is positive may imply that $\partial^3 \pi_A / \partial s_A^3|_{s_A < s_B=s^{nc}} < 0$. Again, since $\partial^2 \pi_A / \partial s_A^2|_{s_A=s_B=s^{nc}} < 0$ a most profitable deviation, if it exists, arises at $s_A = 0 < s^{nc}$.

¹⁸Observe that the firms' strategy spaces are such that "leapfrogging", i.e., deviations for which $A > B^* = 1 - \gamma s^{nc}$, is excluded.

The conclusion of this discussion for all values of θ and γ is that we have to show that

$$\pi_A(s^{nc}, s^{nc}) \geq \pi_A(s_A = 1/2\gamma, s^{nc})$$

and

$$\pi_A(s^{nc}, s^{nc}) \geq \pi_A(s_A = 0, s^{nc})$$

hold. Tedious computations¹⁹ reveal that the above is satisfied if $c \geq 2\theta^2/3\sqrt{3}$.

Adding 1. and 2. completes the proof.

¹⁹Exact computations are available from the authors upon request.

No.	Author(s)	Title
9773	H. Huizinga and S.B. Nielsen	The Taxation of Interest in Europe: A Minimum Withholding Tax?
9774	E. Charlier	Equivalence Scales for the Former West Germany
9775	M. Berliant and T. ten Raa	Increasing Returns and Perfect Competition: The Role of Land
9776	A. Kalwij, R. Alessie and P. Fontein	Household Commodity Demand and Demographics in the Netherlands: a Microeconomic Analysis
9777	P.J.J. Herings	Two Simple Proofs of the Feasibility of the Linear Tracing Procedure
9778	G. Gürkan, A.Y. Özge and S.M. Robinson	Sample-Path Solutions for Simulation Optimization Problems and Stochastic Variational Inequalities
9779	S. Smulders	Should Environmental Standards be Tighter if Technological Change is Endogenous?
9780	B.J. Heijdra and L. Meijdam	Public Investment in a Small Open Economy
9781	E.G.F. Stancanelli	Do the Rich Stay Unemployed Longer? An Empirical Study for the UK
9782	J.C. Engwerda and R.C. Douven	Local Strong d -Monotonicity of the Kalai-Smorodinsky and Nash Bargaining Solution
9783	J.C. Engwerda	Computational Aspects of the Open-Loop Nash Equilibrium in Linear Quadratic Games
9784	J.C. Engwerda, B. van Aarle J.E.J. Plasmans	The (In)Finite Horizon Open-Loop Nash LQ-Game: An Application to EMU
9785	J. Osiewalski, G. Koop and M.F.J. Steel	A Stochastic Frontier Analysis of Output Level and Growth in Poland and Western Economies
9786	F. de Jong	Time-Series and Cross-Section Information in Affine Term Structure Models
9787	G. Gürkan, A.Y. Özge and S.M. Robinson	Sample-Path Solution of Stochastic Variational Inequalities
9788	A.N. Banerjee	Sensitivity of Univariate AR(1) Time-Series Forecasts Near the Unit Root
9789	G. Brennan, W. Güth and H. Kliemt	Trust in the Shadow of the Courts
9790	A.N. Banerjee and J.R. Magnus	On the Sensitivity of the usual t - and F -tests to AR(1) misspecification
9791	A. Cukierman and M. Tommasi	When does it take a Nixon to go to China?

No.	Author(s)	Title
9792	A. Cukierman, P. Rodriguez and S.B. Webb	Central Bank Autonomy and Exchange Rate Regimes - Their Effects on Monetary Accommodation and Activism
9793	B.G.C. Dellaert, M. Prodigalidad and J.J. Louviere	Family Members' Projections of Each Other's Preference and Influence: A Two-Stage Conjoint Approach
9794	B. Dellaert, T. Arentze, M. Bierlaire, A. Borgers and H. Timmermans	Investigating Consumers' Tendency to Combine Multiple Shopping Purposes and Destinations
9795	A. Belke and D. Gros	Estimating the Costs and Benefits of EMU: The Impact of External Shocks on Labour Markets
9796	H. Daniëls, B. Kamp and W. Verkooijen	Application of Neural Networks to House Pricing and Bond Rating
9797	G. Gürkan	Simulation Optimization of Buffer Allocations in Production Lines with Unreliable Machines
9798	V. Bhaskar and E. van Damme	Moral Hazard and Private Monitoring
9799	F. Palomino	Relative Performance Equilibrium in Financial Markets
97100	G. Gürkan and A.Y. Özge	Functional Properties of Throughput in Tandem Lines with Unreliable Servers and Finite Buffers
97101	E.G.A. Gaury, J.P.C. Kleijnen and H. Pierreval	Configuring a Pull Production-Control Strategy Through a Generic Model
97102	F.A. de Roon, Th.E. Nijman and C. Veld	Analyzing Specification Errors in Models for Futures Risk Premia with Hedging Pressure
97103	M. Berg, R. Brekelmans and A. De Waegenaere	Budget Setting Strategies for the Company's Divisions
97104	C. Fernández and M.F.J. Steel	Reference Priors for Non-Normal Two-Sample Problems
97105	C. Fernández and M.F.J. Steel	Reference Priors for the General Location-Scale Model
97106	M.C.W. Janssen and E. Maasland	On the Unique D1 Equilibrium in the Stackelberg Model with asymmetric information
97107	A. Belke and M. Göcke	Multiple Equilibria in German Employment -Simultaneous Identification of Structural Breaks-
97108	D. Bergemann and U. Hege	Venture Capital Financing, Moral Hazard, and Learning
97109	U. Hege and P. Viala	Contentious Contracts
97110	P.J.-J. Herings	A Note on "Stability of Tâtonnement Processes of Short Period Equilibria with Rational Expectations"

No.	Author(s)	Title
97111	C. Fernández, E. Ley, and M.F.J. Steel	Statistical Modeling of Fishing Activities in the North Atlantic
97112	J.J.A. Moors	A Critical Evaluation of Mangat's Two-Step Procedure in Randomized Response
97113	J.J.A. Moors, B.B. van der Genugten, and L.W.G. Strijbosch	Repeated Audit Controls
97114	X. Gong and A. van Soest	Family Structure and Female Labour Supply in Mexico City
97115	A. Blume, D.V. DeJong, Y.-G. Kim and G.B. Sprinkle	Evolution of Communication with Partial Common Interest
97116	J.P.C. Kleijnen and R.G. Sargent	A Methodology for Fitting and Validating Metamodels in Simulation
97117	J. Boone	Technological Progress and Unemployment
97118	A. Prat	Campaign Advertising and Voter Welfare
9801	H. Gersbach and H. Uhlig	Debt Contracts, Collapse and Regulation as Competition Phenomena
9802	P. Peretto and S. Smulders	Specialization, Knowledge Dilution, and Scale Effects in an IO-based Growth Model
9803	K.J.M. Huisman and P.M. Kort	A Further Analysis on Strategic Timing of Adoption of New Technologies under Uncertainty
9804	P.J.-J. Herings and A. van den Elzen	Computation of the Nash Equilibrium Selected by the Tracing Procedure in N -Person Games
9805	P.J.-J. Herings and J.H. Drèze	Continua of Underemployment Equilibria
9806	M. Koster	Multi-Service Serial Cost Sharing: A Characterization of the Moulin-Shenker Rule
9807	F.A. de Roon, Th.E. Nijman and B.J.M. Werker	Testing for Mean-Variance Spanning with Short Sales Constraints and Transaction Costs: The Case of Emerging Markets
9808	R.M.W.J. Beetsma and P.C. Schotman	Measuring Risk Attitudes in a Natural Experiment: Data from the Television Game Show Lingo
9809	M. Büttler	The Choice between Pension Reform Options
9810	L. Bettendorf and F. Verboven	Competition on the Dutch Coffee Market
9811	E. Schaling, M. Hoeberichts and S. Eijffinger	Incentive Contracts for Central Bankers under Uncertainty: Walsh-Svensson non-Equivalence Revisited

No.	Author(s)	Title
9812	M. Slikker	Average Convexity in Communication Situations
9813	T. van de Klundert and S. Smulders	Capital Mobility and Catching Up in a Two-Country, Two-Sector Model of Endogenous Growth
9814	A. Belke and D. Gros	Evidence on the Costs of Intra-European Exchange Rate Variability
9815	J.P.C. Kleijnen and O. Pala	Maximizing the Simulation Output: a Competition
9816	C. Dustmann, N. Rajah and A. van Soest	School Quality, Exam Performance, and Career Choice
9817	H. Hamers, F. Klijn and J. Suijs	On the Balancedness of m -Sequencing Games
9818	S.J. Koopman and J. Durbin	Fast Filtering and Smoothing for Multivariate State Space Models
9819	E. Droste, M. Kosfeld and M. Voorneveld	Regret Equilibria in Games
9820	M. Slikker	A Note on Link Formation
9821	M. Koster, E. Molina, Y. Sprumont and S. Tijs	Core Representations of the Standard Fixed Tree Game
9822	J.P.C. Kleijnen	Validation of Simulation, With and Without Real Data
9823	M. Kosfeld	Rumours and Markets
9824	F. Karaesmen, F. van der Duyn Schouten and L.N. van Wassenhove	Dedication versus Flexibility in Field Service Operations
9825	J. Suijs, A. De Wagenaere and P. Borm	Optimal Design of Pension Funds: A Mission Impossible
9826	U. Gneezy and W. Güth	On Competing Rewards Standards -An Experimental Study of Ultimatum Bargaining-
9827	M. Dufwenberg and U. Gneezy	Price Competition and Market Concentration: An Experimental Study
9828	A. Blume, D.V. De Jong and G.R. Neumann	Learning in Sender-Receiver Games
9829	B.G.C. Dellaert, J.D. Brazell and J.J. Louviere	Variations in Consumer Choice Consistency: The Case of Attribute-Level Driven Shifts in Consistency
9830	B.G.C. Dellaert, A.W.J. Borgers, J.J. Louviere and H.J.P. Timmermans	Consumer Choice of Modularized Products: A Conjoint choice Experiment Approach

No.	Author(s)	Title
9831	E.G.A. Gaury, H. Pierreval and J.P.C. Kleijnen	New Species of Hybrid Pull Systems
9832	S.J. Koopman and H.N. Lai	Modelling Bid-Ask Spreads in Competitive Dealership Markets
9833	F. Klijn, M. Slikker, S. Tijs and J. Zarzuelo	Characterizations of the Egalitarian Solution for Convex Games
9834	C. Fershtman, N. Gandal and S. Markovich	Estimating the Effect of Tax Reform in Differentiated Product Oligopolistic Markets
9835	M. Zeelenberg, W.W. van Dijk, J. van der Pligt, A.S.R. Manstead, P. van Empelen and D. Reinderman	Emotional Reactions to the Outcomes of Decisions: The Role of Counterfactual Thought in the Experience of Regret and Disappointment
9836	M. Zeelenberg, W.W. van Dijk and A.S.R. Manstead	Reconsidering the Relation between Regret and Responsibility
9837	M. Dufwenberg and G. Kirchsteiger	A Theory of Sequential Reciprocity
9838	A. Xepapadeas and A. de Zeeuw	Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital
9839	M. Lubyova and J.C. van Ours	Unemployment Durations of Job Losers in a Labor Market in Transition
9840	P. Bolton and X. Freixas	A Dilution Cost Approach to Financial Intermediation and Securities Markets
9841	A. Rustichini	Minimizing Regret: The General Case
9842	J. Boone	Competitive Pressure, Selection and Investments in Development and Fundamental Research
9843	H.L.F. de Groot	Macroeconomic Consequences of Outsourcing. An Analysis of Growth, Welfare, and Product Variety
9844	U. Gneezy, W. Güth and F. Verboven	Presents or Investments? An Experimental Analysis
9845	A. Prat	How Homogeneous Should a Team Be?
9846	P. Borm and H. Hamers	A Note on Games Corresponding to Sequencing Situations with Due Dates
9847	A.J. Hoogstrate and T. Osang	Saving, Openness, and Growth
9848	H. Degryse and A. Irmen	On the Incentives to Provide Fuel-Efficient Automobiles

P.O. BOX 99450 5000 LE TILBURG THE NETHERLANDS

Bibliotheek K. U. Brabant

17 000 01420507 5