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AN INTERNAL FUEL EFFICIENCY CREDIT MARKET MECHANISM FOR MEETING THE CAFE STANDARD: INTERNALIZING A REGULATION CAUSED EXTERNALITY

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ABSTRACT

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The paper develops and analyzes an internal market based mechanism that enables a decentralized enterprise to meet the conditions of the Corporate Average Fuel Economy (CAFE) regulations. Divisions that produce vehicles with fuel economy (miles per gallon fuel) above the regulatory requirement receive Fuel Efficiency Credits (FEC). These credits can be sold in an internal FEC market to divisions that produce vehicles with fuel economy levels below the regulatory requirement. The FEC available for sale by fuel efficient vehicle production and the FEC needed as a condition of production of fuel inefficient vehicles are tied to the respective fuel efficiency levels. Experimental tests demonstrate that the enterprise can achieve near profit maximum levels while continuing to operate through decentralized profit centers. The FEC market "internalizes" the externality across divisions created by the CAFE regulation. The behavioral model supported by the data suggests that the policy can be successfully crafted to include multiple firms trading FECs.

An Internal Fuel Efficiency Credit Market Mechanism
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This paper develops and explores a mechanism for a decentralized vehicle producer to meet the challenges that are created by the Corporate Average Fuel Economy (CAFE) regulation. The regulation requires that the average fuel economy across all vehicles produced by the enterprise be at least as great as a regulatory minimum. By linking the production levels of decentralized divisions, the regulation creates an externality between otherwise independent profit centers specialized for the production and sale of different types of vehicles. That is, previously independent divisions become connected by a new company-wide system constraint that the average fuel economy exceeds some constant. The mechanism studied here rests on an internal market for Fuel Efficiency Credits (FEC). The analysis is based on a laboratory experimental testbed methodology. The issue addressed is whether a special market architecture in which decisions are made by decentralized divisions subject to a system-wide CAFE standard regulatory constraint is profit-maximizing from an integrated company point of view. Can the mechanism enable a vehicle manufacturer to meet the CAFE standards most profitably while operating as a decentralized organization?

Our results indicate that high aggregate efficiency levels can be achieved through this market institution. The manufacturer's performance, as measured by vehicle production, profits, and fuel-efficiency, can be substantially enhanced over a benchmark process of scaling back to the CAFE standard from the unconstrained output levels. The theoretical framework and the experimental methods used in the paper can be modified and adapted to account for additional complexities, such as allowing for fuel efficiency credit trading between firms.

1. Introduction[1]

The Corporate Average Fuel Efficiency standard (CAFE) for passenger cars and light duty trucks was enacted by Congress in 1975 with the aim of improving vehicle fuel efficiency in a period of high oil prices. In short, the CAFE regulation requires each car manufacturer to meet a standard for the sales-weighted fuel economy for the entire fleet of vehicles sold in the USA in each model year; fuel economy, measured in miles per gallon (mpg), is defined as the average mileage traveled by a vehicle per gallon of gasoline or equivalent amount of other fuel.[2] While the original goal of the program was for every seller of automobiles in the US to achieve a minimum sales-weighted average fuel efficiency of 27.5 Miles per Gallon by 1985, a bill increasing the standard to 35 MPG by 2020 recently passed.

Although previous research has analyzed the environmental effects of the CAFE regulation and its aggregate impact on vehicle production and fuel prices (Mayo and Mathis, 1988; Greene, 1990; Goldberg, 1998), few studies have examined its implications from the perspective of the organization of a profit-maximizing vehicle manufacturer. The focus of this paper is to analyze methods that might be used to enable a vehicle manufacturer to meet the CAFE standards most profitably while operating as a decentralized decision-making entity. The manufacturing firm is assumed to be a decentralized organization with independent divisions motivated by maximizing division profits and subject to a system-wide CAFE standard regulation. The divisions control the number of vehicles produced, and the efficiency characteristics of those vehicles, which, in turn determine vehicle cost and market demand. For the purposes of the exercise studied here, both vehicle cost and market demand are known for given vehicle characteristics and production levels.

Several relevant questions regarding the operation of such a decentralized decision-making process consistent with the CAFE standard regulation arise. These questions motivate the research. Do the decisions of decentralized profit centers lead to profit-maximizing outcomes from an integrated company point of view? What are the effects of this market institution on the firm's total production and its composition? What are the effects of the CAFE standard in terms of the manufacturer's overall fuel efficiency?

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[2] A detailed discussion of the CAFE standard regulation exceeds the purposes of this paper. An excellent overview can be found in Crandall (1985, 1990).

In order to address these questions, we use an experimental strategy to analyze the functioning of an internal market for Fuel Efficiency Credits (FEC) in which organized trading and FCE pricing between the different divisions of the manufacturing firm occurs. Divisions producing fuel efficient vehicles produce FEC as a joint product with vehicle production; the FEC produced can be sold at the prices that emerge from the internal FEC market, and revenues from FEC sales contribute to the FEC producing division profits. In contrast, divisions producing fuel inefficient vehicles must acquire FEC with each vehicle produced; the FEC are purchased from those divisions that produce FEC, and the prices paid are determined by the internal competitive market. The cost of FEC is a cost of production to the division that must purchase them and thus reduces division profits. The objective is to create a process that leads independent divisions within the vehicle-manufacturer to the same profit maximizing position for the firm as a collective, as would be the case if an "all knowing" centralized decision-maker made all decisions for all divisions.

The remainder of the paper is organized as follows. Section 2 briefly reviews the theory underlying the operation of an internal Fuel Efficiency Credit (FEC) market mechanism for meeting the CAFE standard. Section 3 presents the experimental procedures and design implemented to examine the performance of this market institution and its implications in terms of the manufacturing firm's production, profits, and total fuel economy. Section 4 discusses the main empirical results of the experiments from two perspectives. The first is a type of proof of principle. Does the system do what it is supposed to do? The second is a check on the internal consistency of the design. Does it do it consistently with the principles at the foundations of the design? Section 5 concludes, and Appendices I and II contain information about the computer software and the instructions used in the experimental sessions.

2. The Mechanism Architecture

We analyze a market exchange process in which "fuel economy" permits (FEC) are traded between different divisions of a vehicle-manufacturing firm in an open market at a price P. Let $M_{i,r}$ be the number of FEC held by division i, $i = 1,...,n$, which produces vehicle type r, $r = 1,...,R,$ with a miles per gallon performance (mpg) equal to α_r. The CAFE standard regulation requires that the average miles per gallon (mpg) value of the cars sold by the manufacturer must not be above a certain value *K*. In the context of the mechanism (the market exchange process) under analysis, assume that, as a form of internal regulation, for all divisions i, types of vehicle r, and production $q_{i,r}$, it must be the case that:

$$M_{i,r} \geq (K - \alpha_r)\ q_{i,r} \qquad (1).$$

Thus:

- if $\alpha_r > K$, division i can create and sell permits in the internal FEC market up to the magnitude for which (1) is satisfied – where the constraint allows negative holding;
- if $\alpha_r < K$, division i must buy FEC to produce vehicles.

Note that, given the constraint that the net supply of permits among the manufacturer's divisions must be zero. Thus, the system must satisfy the equation:

$$\sum_i \sum_r M_{i,r} = 0\ . \qquad (2),$$

Substituting in (1) and assuming equality yields:

$$\sum_i \sum_r (K - \alpha_r)\ q_{i,r} = 0$$

$$K \sum_i \sum_r q_{i,r} - \sum_i \sum_r \alpha_r q_{i,r} = 0$$

which satisfies the CAFE regulation standard that

$$K \geq \frac{\sum_i \sum_r \alpha_r q_{i,r}}{\sum_i \sum_r q_{i,r}} \qquad (3).$$

Thus, the constraints enforced by the mechanism guarantee that the CAFE regulation is satisfied as a technical guarantee. Notice that this is done in the absence of an overall, centralized accounting and balancing of production levels.

3. Mechanism Theoretical Behavior

The analysis is contained in three sections. First the equilibrium behavior is analyzed for the case in which the fuel efficiency levels of all types of vehicles are fixed. Thus, the problem with which the system is confronted is to determine the optimal level of production for each vehicle.

The second section analyzes the case in which each division produces only one type of vehicle but the fuel efficiency level of that vehicle can be adjusted within the technical and cost parameters. Finally, the third section generalizes the theoretical model to the case of multiple firms. Although the experimental methodology implemented in this paper is explicitly aimed at examining the performance of a single firm the mechanism itself can be generalized to multiple firms. That is, the internal Fuel Efficiency Credit (FEC) market mechanism for meeting the CAFE standard in a single firm can be extended to multiple firms who trade FEC each operating with its own CAFE standard. Section 3.3 illustrates the property.

3.1 Fixed Fuel Efficiency Levels

Our attention now turns to models of behavior. In this setting, and assuming that all divisions have an initial endowment of 0 FEC, division i's profit maximization problem is then given by:

$$\max_{q_{i,r}} \; V_{i,r}\left(q_{i,r}\right) - P\,M_{i,r} \tag{4),}$$

where $V_{i,r}$ is the profitability of vehicle of type r produced by division i, and P, $M_{i,r}$ and $q_{i,r}$ are defined above. Under competitive conditions, profit maximization takes place when

$$\frac{\partial V_{i,r}}{\partial q_{i,r}} - P\left(K-\alpha_r\right) = 0 \tag{5}$$

which implies

$$\frac{\dfrac{\partial V_{i,r}}{\partial q_{i,r}}}{\left(K-\alpha_r\right)} = P \tag{6).}$$

The behavioral equations 5 and 6, together with the system balancing equation (1) and (2) define equilibrium for the firm. It follows from (6) that the value of the marginal output is negative at the optimum for those vehicle producers with mpg over K. This means that they are producing vehicles beyond what would be profitable under no CAFE constraint. The incentive to do so is created by the profits due to FEC sales to other divisions.

The equilibrium of the system is the profit maximizing optimum of the firm subject to the CAFE constraint given the fuel efficiencies of the individual vehicles produced. If the technology is fixed in the sense that the efficiency levels of the vehicles produced by the different divisions are fixed, then the levels of production will be coordinated to achieve a system profit maximum. That is, for a fixed efficiency levels of individual vehicles the equilibrium of the decentralized market exchange process determined by (5)-(6) satisfies the optimal conditions of the solution to the vehicle-manufacturer's centralized profit maximization problem:

$$\max \sum_i \sum_r V_{i,r}\left(q_{i,r}\right)$$

subject to:

$$\lambda_r : Q_r - \sum_i q_{i,r},$$

$$\lambda_g : \sum_r \alpha_r Q_r - K \sum_r Q_r,$$

where Q_r is the total production of vehicles of type r by all divisions. The Lagrange multipliers λ_r, $r = 1, \ldots, R,$, are the marginal value of producing an additional car of type *r*. The multiplier λ_g, on the other hand, is a measure of the implicit marginal system benefit of increasing the CAFE regulation standard *K*; actually, it is the marginal system benefit of increasing $z,$ where $z = \sum_r \alpha_r Q_r - K \sum_r Q_r$.

The Lagrangian problem – assuming K and z constant - is thus:

$$\max_{\substack{q_{i,r},\ i=1,\ldots,n;\ r=1,\ldots,R \\ Q_r, \lambda_r,\ r=1,\ldots,R \\ \lambda_g}} H = \sum_i \sum_r V_{i,r}\left(q_{i,r}\right) + \sum_r \lambda_r \left(Q_r - \sum_i q_{i,r} \right) + \lambda_g \left(\sum_r \alpha_r Q_r - K \sum_r Q_r - z \right) \tag{7}$$

with first order conditions – assuming that the constraints are satisfied – given by:

$$\frac{\partial V_{i,r}}{\partial q_{i,r}} = \lambda_r \tag{8}$$

$$\lambda_r + \lambda_g \left(\alpha_r - K\right) = 0 \tag{9}$$

so that

$$\lambda_g = \frac{\frac{\partial V_{i,r}}{\partial q_{i,r}}}{\left(K - \alpha_r\right)} \quad (10).$$

It follows from (5)-(6) and (8)-(10) that the equilibrium of the decentralized market exchange process satisfies the conditions of the centralized (mathematical) optimum; in addition, the CAFE regulation standard is also satisfied, with the marginal cost of the CAFE constraint properly identified in $P = \lambda_g$.

3.2 Variable Fuel Efficiency Levels

The model has even more powerful predictions that include the case in which divisions can change the efficiency levels of their vehicles in response to market incentives. That is, if the different divisions can change the miles per gallon (mpg) fuel efficiency of the vehicles they produce, an additional equation becomes important to describe their behavior. The mpg parameter becomes part of the valuation function for vehicles of type r, since it influences both demand and cost. Hence, an additional equation is added to the First-Order Optimization Condition for vehicle producers:

$$\frac{\partial V_{i,r}}{\partial \alpha_r} = P \ \frac{\partial M_{i,r}}{\partial \alpha_r} \quad (11).$$

Equation (11) implies that the value of the marginal change of mpg is balanced against the change of revenue from FEC sales or change of cost of FEC purchases that will result from the technological change. Therefore, if division i sees a profit that would result from a mpg change, it will make the change as guided by the price of FEC.

Thus, the behavioral model of decentralized division choices become profit maximizing for the firm operating under CAFE constraints. Theoretically, this takes place without centralized decision making other than the creation and enforcement of the rules of the process. The technologies and market conditions faced by the individual divisions need not be known by the centralized administration of the firm. Yet, each division acting in its own interest leads to the optimum fuel efficiency of individual vehicles and the optimum production of each from the centralized firm point of view.

3.3 Generalization to multiple firms within an industry

The theoretical model and behavioral mechanism can be easily extended in order to capture the efficiency advantages of coordination across multiple firms in an industry, each operating with its own CAFE standard, with FEC traded between firms. While only trading of FEC takes place, it is as if one of the firms in the industry, say firm A, could contract with another firm, firm B, to produce vehicles. Vehicles produced in this manner would count ONLY as firm A's production for the purpose of CAFE, as if the vehicles were produced directly by firm A and firm B had nothing to do with it. Firm B would therefore meet the CAFE standard based on the vehicles that counted towards its own production and firm A would meet the standard based on its own production plus the production contracted to firm B.

That the CAFE standard would be met for the industry as a whole is easy to see. Let $M_{i,j}$ be the FEC held by division i of firm j. When the CAFE standard is applied to each firm independently, the system satisfies the ("material balances") equation:

$$\sum_i M_{i,j} = 0 \ \ \forall j \qquad (12).$$

Adapting the notation of Sections 3.1 and 3.2, let $q_{i,j}$ be the number of vehicles produced by division i of firm j, $\alpha_{i,j}$ the vehicle efficiency (mpg) for the vehicles produced by it, and let K denote the CAFE standard. Then:

$$M_{i,j} = \left(K - \alpha_{i,j}\right) q_{i,j} \ \ \forall i, j \qquad (13).$$

Substituting (13) into (12) and simplifying, we get

$$\sum_i \left(K - \alpha_{i,j}\right) q_{i,j} = 0 = K \sum_i q_{i,j} - \sum_i \alpha_{i,j} q_{i,j} \ \ \forall j \qquad (14)$$

which is recognized as the CAFE standard:

$$K = \frac{\sum_i \alpha_{i,j} q_{i,j}}{\sum_i q_{i,j}} \tag{15}$$

where K is the average fuel economy for vehicles produced by the firm.

If FEC trades across firms are allowed, the industry must satisfy the system-wide (material balances) equation:

$$\sum_j \sum_i M_{i,j} = 0 \qquad (16).$$

Substituting (13) into (16) and simplifying as above, we have

$$\sum_j \sum_i \left(K - \alpha_{i,j}\right) q_{i,j} = 0 = K \sum_j \sum_i q_{i,j} - \sum_j \sum_i \alpha_{i,j} q_{i,j} \tag{17}$$

which can be recognized as a system-wide constraint that the average fuel economy of vehicles collectively produced by the industry equals the CAFE standard

$$K = \frac{\sum_j \sum_i \alpha_{i,j} q_{i,j}}{\sum_j \sum_i q_{i,j}} \qquad (18).$$

Clearly, (18) is implied by (15), but the economics of (18) is not the same as that implied by (15). The consequences would be that, as long as all firms faced the same CAFE regulation, then the industry-wide mpg per vehicle produced would meet the CAFE standard. A reasonable conjecture is that it would increase the number of vehicles produced, lower the social cost of meeting the CAFE standard and increase the incentive to create fuel efficiency technologies. Firms would be able to specialize in producing vehicles of various fuel efficiencies, with those firms with a comparative advantage in producing efficient vehicles receiving financial incentives to do so from the firms that produce inefficient vehicles.

4. Testbed Experimental Procedures and Design

We use an experimental methodology to explore the mechanism described in Section 2. We will ask two different types of questions. (1) Does the mechanism perform as desired? That is, do the aggregate, profit producing predictions hold? (2) Does the mechanism behave according the principles used to design it? That is, does the mechanism do what it does for understandable reasons? Basically, the strategy to test whether individuals' system behavior and individual behavior are consistent with the implications of the theoretical model presented in Section 2 and to assess the impact of the market exchange process on the firm's aggregate production, profits, and fuel economy. In the next subsections, we describe the procedures and the experimental design implemented in our empirical analysis.

4.1 Experimental Procedures

The subjects in the experiments were students recruited from Caltech by a general request for people to put themselves in a database if they were interested in participating in experiments. The day before the experiment, invitations were sent via e-mail recruiting subjects from that database. A total of 73 students participated in 8 experimental sessions, with 10 participants per session (some students participated in more than one session). Several of the students had prior experience with economics experiments in general, and few subjects also had prior experience with market experiments in particular.

Experiments were computer-based, conducted in Caltech's Laboratory for Experimental Economics and Political Science (EEPS); a screenshot of the software used in the experiment and the computer guide provided to the subjects is presented in Appendix I.[3] Upon entering the lab, participants were randomly assigned a seat in front of a computer, an identification number (similar to a particular manufacturing division), and were given a set of instructions. For purposes of discussion in this report we will refer to the position of a subject in the experiment as a "division" so consistency with the model and the interpretations of the results can be maintained. The instructions described the general setting of the market environment, the tasks to be performed by the subject and the payment schemes, and included examples of how to perform the computations required to make the relevant decisions. In addition, each participant was provided incentives in the form of a series of tables with redemption values obtained from the production of the different types of vehicle available to him; information regarding the different mpg values was private. Each subject "produced" one type of vehicle, made a quantity decision regarding the production level

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[3] The software used is an adaptation of Caltech EEPS Marketscape program. It is capable of supporting multiple markets and multiple production technologies.

and, depending on the experiment, made a choice of the mpg of the vehicle. A sample of the instructions is presented in Appendix II.

Each experimental session consisted of four fifteen-minute periods, preceded by a fifteen minute practice period for which subjects did not receive payment. During each period, asks and bids for FEC were recorded in an open book, and transactions were conducted in an open market, with information on prices and quantities traded publicly observed in continuous time. At the end of each period, subjects were given 5 minutes to record their earnings and the trades they had made in the FEC market. At the end of the session they were asked to compute their total earnings and submit the final amount to the experimenters; the calculations were verified by the experimenters, based on the computer logs. Subjects earned between $10 and $60 for a two-hour experiment, depending on their performance, with most subjects earning close to an average of $40.

4.2 Experimental Design

Two different experimental designs were implemented, Design A and Design B. In each design subjects made decisions regarding production levels. In Design B, subjects also made decisions about the mpg of the vehicle.

Design A) Fixed MPG: each subject was assigned a predetermined mpg value for the vehicle production the subject controlled and was not allowed to change it during the experiment. Subjects had to decide their optimal production level given their mpg constraints, taking into account profits from the sales of vehicles and sales/purchases of FEC in the FEC market.

Design B) Variable MPG: each subject was provided four possible levels of mpg. The choice of mpg influenced vehicle sale profitability. In the first period of the experiment, subjects were assigned a predetermined mpg value as in design A and had to choose only the production level. In the second and later periods, subjects had to choose both the efficiency level of the vehicle – defined by the mpg value - and the production level.

Three experiments of Design A and five experiments of Design B were conducted. In both experimental designs, the CAFE mpg requirement – the value of K, in Section 2 - was set to 20. In experiments in which design A was implemented, 4 subjects were assigned mpg values higher than 20 – i.e., they produced fuel-efficient vehicles and were thus sellers of FCE -, 5 subjects were assigned mpg values lower than 20 – they produced fuel-inefficient vehicles and were buyers of FCE -, and one agent was assigned mpg of 20. In experiments in which design B was implemented, 5 subjects were sellers of mpg and 5 subjects were buyers of FCE in equilibrium. Subjects' profits are determined as follows:

FEC buyers: Profit = Value received from vehicles produced - cost of FEC for the production of vehicles

FEC sellers: Profit = Value received from vehicles produced + revenue received from the sale of FEC where, as mentioned in the introduction, both vehicle cost and market demand are known for given vehicle characteristics and production levels.

Subjects' values were generated according to the following formula, which is the experimental equivalent of a net profit function before any internal tax or transfer price for a vehicle:

$$\text{Total Value} = 100s \times \mathrm{Q}_s \text{ - } \frac{5s}{2}\mathrm{Q}_s^2$$

$$\text{Marginal (unit Value)} = \text{100s -5s} \times \mathrm{Q}_s \tag{12}$$

where: s can be interpreted as the size or the weight of a vehicle type r and Q_s is the number of unites produced of vehicle of size s.

Let $Y_s = \left(\alpha_s - K\right)$ denote the mpg value of a vehicle of size s in excess of the CAFE mpg requirement, where, as mentioned above, we set $K = 20 = \frac{40}{s}$, so that $\alpha_s = \frac{40}{s} + Y_s$. Then, denoting by z the Lagrangian multiplier, we have:

$$\sum_s \left[s\left(100 - \frac{5}{2}Q_s\right)Q_s - s^{1/4} \times 3.125 \times Y_s^2 \right] + z\sum_s \left(\frac{40}{s} + Y_s\right)Q_s - 20\sum_s Q_s \tag{13}$$

with first order conditions

$$s\ \left(100 \text{ - } 5\ Qs\right) \text{ - } [s^{1/4} \times 3.125\ \times Y_s^2]\ + z\ \left(\frac{40}{s} + Y_s - 20\right) = 0 \tag{14}$$

and

$$\text{-}[s^{1/4} \times 3.125\ \times\ 2\ Y_s]\ Q_s\ +\ z\ Q_s\ = 0 \tag{15}$$

From equation (14), the equilibrium FEC price is z times the difference between the mpg of a vehicle of size s and 20; from equation (15), $z = [s^{1/4} \times 3.125 \times 2\ Y_s]$, which is additional cost per vehicle due to a marginal increase in fuel economy.

The parameters of both experimental designs are summarized in Tables 1 and 2; the set of redemption values for each of the mpg values available for experimental subjects is presented in Appendix III.

[Table 1 here]

[Table 2 here]

Figure 1 below presents the equilibrium in FEC market resulting from the demand and supply of FEC induced by the parameters in the two experimental designs.[4]

[Figure 1 here]

Given the parameters and the resulting equilibria for each experimental design, Table 3 compares the system-wide production, profit and fuel-efficiency levels under three alternative baseline scenarios: a) The centralized (mathematical) optimum subject to CAFE constraint; b) the equilibrium that would exist if no CAFE regulations exist; and c) a natural administrative response to CAFE: leaving untouched the production of vehicles that have mpg above CAFE and proportionally scaling back the production of all vehicles with mpg less than CAFE until the overall CAFE standard is met. For both experimental designs, the aggregate production and fuel-efficiency levels under the mathematical optimum subject to the CAFE constraint are higher than in the scenario with no CAFE constraint, and it the centralized solution also leads to higher production and profit levels than the administrative response.

[Table 3 here]

5. Empirical results

The results are divided into three parts. The first part overviews our main findings about prices and quantities traded in the FEC market. The second part reports the subject's vehicle-production and the system efficiency levels attained under both experimental designs. Finally, the third part presents the aggregate results regarding the firm's production, profits from vehicles

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[4] In the case of Design B, Figure 1 illustrates the equilibrium in the FEC market for periods 2 – 4, in which subjects choose both the fuel-efficiency and the production levels of the vehicles; the equilibrium for period 1 is the same as under Design A.

produced and average fuel-efficiency and compares them to the results obtained under the alternative baseline scenarios described in Table 3.

5.1 Prices and quantities traded in the FEC market

Figures 2 and 3 plot the time-series of the trade prices in the FEC market for all experiments under Designs A and B, respectively. As is clear from the figures, trade prices exhibit considerable variability, particularly under the variable mpg design (Design B). Note, however, that prices tend to converge to the equilibrium level as time goes on. This pattern is evident in Figure 2: under the fixed mpg design, the initial trades take place at relatively high prices, but convergence towards the equilibrium is observed at the end of virtually every period. In the case of the variable mpg design, the "learning" process takes considerably more time due to the complexities induced by the different mpg choices available for each subject and the fact that subjects shift from an initial period in which the mpg values are given (Period 1) to choosing both the fuel-efficiency and the production levels of the vehicles they produce. Nonetheless, despite the difficulties involved in Design B, Figure 3 indicates that trade prices also tend to converge to the equilibrium levels as subjects' performance improves with experience; averaged over the entire experiment, trade prices tend to be relatively close to the equilibrium price, and in fact the average of Period-4 trade prices for all experiments under Design B 17.85, quite near to the equilibrium level of 16 represented in Figure 1.

[Figure 2 here]

[Figure 3 here]

In order to examine convergence of prices towards the equilibrium-level, we regressed the distance between the observed and the equilibrium prices on the time of the transactions for all sessions under each experimental design, where we used the ordinal measure of time that is updated after each trade (Hirota, Hsu, Plott and Rogers, 2005). We fit a simple fixed effects model in which a common time-slope is assumed for all the sessions under each experimental design while the intercept is allowed to vary from session to session.

$$P_t - P^* = \beta_0 \text{ Session} + \beta_1 \text{ Time} + \varepsilon_t$$

where P^* is the FEC equilibrium price under each experimental design. The results, reported in Table 4, show that the prices move towards the equilibrium-level under both Design A and Design B. The movement towards the equilibrium price is on average 0.04 francs with each trade for

Design A, and 0.07 francs for Design B. In both cases, the coefficients of time are significant at the 0.01 level.

[Table 4 here]

In addition, Spearman's *rho* (Hollander and Wolfe, 1999) for the association between the price changes between in the FEC market, $\Delta P_{t+1} = P_{t+1} - P_t$, and the excess demand of the previous period, $ED_t = D_t - S_t$, is 0.21 under both experimental designs, and the hypothesis of a null or negative correlation between both variables can be rejected at the 0.01 level. Thus, these results indicate that, despite the complexity of the market architecture used in the experiment, price dynamics in the FEC market is in line with the predictions of the classical theory of economic dynamics (McKenzie, 2002; Mukherji, 2002, 2003). Furthermore, it is interesting to note that convergence towards the equilibrium-level price under the variable mpg design tends to occur despite the fact that subjects do not necessarily choose the optimal mpg value for the vehicles they produce. Figure 4 plots the choice of mpg values for each subject under Design B, discriminated by period. As seen in the Figure, there is wide variation in the pattern and timing of choices among divisions and experiments. For some divisions and experiments, mpg choices “overshoot” and then pullback, indicating that the market is guiding the divisions through disequilibria towards the optimum; in some other cases, subjects fail to choose the fuel-efficiency level of their vehicles in accordance with the theoretical predictions.

[Figure 4 here]

Table 5 presents the average FEC traded in each round of every experiment under Designs A and B, as percentage of the equilibrium quantities reported in Figure 1. In virtually all of the experiments, the average volume of FEC actually traded in the market is around or above 90% of the equilibrium volume, though, again, variability is much higher under Design B. In the fixed mpg design, quantities traded as a percentage of the equilibrium volume tend to increase rapidly during the first rounds of the experiments. The pattern of trades is less clear in the variable mpg design: in some experiments (e.g., 09/23/2007 and 11/13/2007) trading is very high during the first period and tends to stabilize as time goes on, while in others (e.g., 11/11/2007) trades show substantial fluctuations over periods. Overall, however, we cannot reject the hypothesis that the variance of efficiency levels under Design B is not statistically different from those under Design A at the usual confidence levels.[5]

[Table 5 here]

5.2 Vehicle production and efficiency levels

Figures 5 and 6 plot the average production levels by division and period under both experimental designs. The evidence presented in both figures indicates that observed production convergence towards vehicle-production equilibrium levels tends to occur faster and more smoothly under Design A. Under Design B, there is more disparity between divisions and, in particular, some of the divisions producing fuel-efficient vehicles tend to produce more than the equilibrium quantity in response to high FEC prices.

[Figure 5 here]

[Figure 6 here]

Two-sample t-tests for the absolute value of the difference between the theoretical equilibrium and the per-period observed production for each division under both designs show that differences tend to be larger under Design B for many of the divisions (Table 6). Nonetheless, as seen in Figure 6, even in the variable mpg design observed production levels tend to approach the theoretical equilibrium as the number of periods increase, again suggesting that subjects' and system's performance tends to increase with experience.

[Table 6 here]

In order to further explore subjects' behavioral patterns regarding vehicle production, we run a Poisson regression for the absolute value of the difference between the theoretical equilibrium and the observed production as dependent variable. The predictors included in the model are: *Period*; *Price*, measured as between the average trade prices in the FEC market during the period; *Design B*, a dummy variable for the variable-mpg design; and *Fuel Efficiency, measured in miles-per-gallon*. The latter variable was coded in two different ways: i) as a dichotomous variable taking the value of 1 for fuel economy efficient divisions – i.e., those with mpg values over 20 – and 0 for fuel economy inefficient divisions (Specification 1); and ii) on an eight point-scale, in ascending order according to each division's mpg value (Specification 2). The basic model is then:

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[5] The p-values of Bartlett's and Fligner-Killeen' tests of the null hypothesis that the variances in efficiency levels under the two experimental designs are the same are 0.11 and 0.53, respectively (Bartlett, 1937; Conover, Johnson and Johnson, 1981)

$$\left| Y_{i,t} - Y_i^* \right| \sim Poisson\left(\theta_{i,t}\right)$$
$$\theta_{i,t} = \beta_0 + \beta_1\ t + \beta_2\ \text{Price}_t + \beta_3\ \text{Design B} + \beta_4\ \text{Fuel Efficiency}_{i,t} + \varepsilon_{i,t}$$

where $Y_{i,t}$ is the observed production for division i at period t, and Y_i^* is the theoretical equilibrium production level for that division, under each experimental design.

The results of both specifications, reported in Table 7, are in line with our expectations: the differences between the observed production quantities and the theoretical equilibrium production quantities decline with the number of periods, and they are larger for high fuel-efficiency divisions and for the variable-mpg design. Our results imply that, *ceteris paribus*, the differences under the variable mpg design are 2.2 units higher across subjects than under the fixed mpg design, and that, for a given design, the differences are 2.4 units larger for fuel-efficient divisions. In contrast, the average trade price in the FEC market has no impact on the dependent variable after controlling for the other regressors; the reason for this is that, as seen in Figures 2 and 3, trade prices tend to decline with the number of periods.[6]

[Table 7 here]

In line with the definition of experimental market efficiency first developed by Plott and Smith (1978), we measure efficiency levels as the ratio between the actual profits obtained from vehicles produced to the maximum possible profits subject to the CAFE constraint. Table 8 reports the efficiency levels attained in the three experiments conducted under Design A and the five experiments conducted under Design B.

[Table 8 here]

Again, efficiency levels under both experimental designs tend to increase over the periods. However, some interesting differences emerge between the experimental designs, illustrating the higher complexity of the variable mpg design from the perspective of subjects' decision-making process. For Design A, efficiency levels increase almost uniformly with the number of periods and become close to the maximum possible under such constraint, indicating that that the choice of vehicle production levels approaches the optimum. Efficiency levels under Design B also tend to increase with the number of periods, illustrating that the choice of vehicle moves in the optimum

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[6] The results remain virtually identical if *Price* is defined as the difference between the average trade price in each period and the equilibrium price.

direction and the vehicle production levels given mpg choice are also moving the direction of greatest profitability as the number of periods increase. However, efficiency is much more variable both across periods and experiments under Design B when compared to Design A. Moreover, for one of the sessions (11/11/2007), some subjects apparently failed to understand the total impact on profits of changing mpg, and thus did not adjust their mpg choice in the direction implied by the theoretical model.

Figure 7 allows us to contrast the relative efficiency attained under both experimental designs, comparing the efficiency levels in experiments with fixed and variable mpg to a baseline level determined by the maximum possible profitability with mpg fixed divided by maximum possible potential profits if the mpg is not fixed.

[Figure 7 here]

The evidence presented in Figure 7 reveals that substantive efficiency gains result not only from better coordinated output levels, but also from changing the mpg values in those experiments in which the mpg was allowed to be determined endogenously. Also, note that in the session conducted on 11/11/2007, the failure of some subjects to adjust their mpg choice led to relative efficiency levels that are close to those attained under Design A. Nonetheless, we cannot reject the null hypothesis that the relative efficiency levels under Design B are higher than under Design A: the p-value of the Wilcoxon Mann-Whitney test (Hogg, McKean and Craig, 2005) for the null hypothesis $\text{Relative Efficiency}_A - \text{Relative Efficiency}_B \leq 0$ is 0.982, and 0.991 when stratified by period.

5.3 Aggregate Scenario Comparisons

In this section we compare the experimental results regarding the vehicle-manufacturer's production, profit from vehicle production and average fuel-efficiency levels with those obtained under three baseline scenarios described in Section 3. Table 9 presents the results for both experimental designs, where the experimental outcomes are averaged over all periods and experiments.

Despite the fact that subjects often failed to adjust completely according to the theoretical model[7], the comparison of the results reported in Table 9 with those in Table 3 shows that the experimental outcomes under Designs A and B are relatively close to the centralized (mathematical)

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[7] See Section 4.1 of this report.

optimum subject to the CAFE standard regulation. Hence, the system-wide results seem to be quite robust to miscalculations and poor performance of individual agents. Moreover, production and average fuel-efficiency levels of the vehicles produced are on average higher than in the scenario with no CAFE constraint. The p-values of the signed-rank Wilcoxon tests (Hollander and Wolfe, 1999) for the hypothesis that the per-period experimental production levels are equal or greater than in the equilibrium without the CAFE constraint are 0.94 for Design A and 0.99 for Design B, and the hypothesis that the efficiency levels are less or equal than in the scenario with no regulation are rejected at the 0.1 level for both experimental designs. Also, as seen in Table 9, the decentralized decision-making process leads to substantially higher profits and production levels than those obtained using proportional rescaling (administrative response).

[Table 9 here]

6. Discussion and Conclusions

This paper analyzes methods that can be used to enable a vehicle manufacturer to meet the CAFE standards most profitably while operating as a decentralized organization with no centralized administrative decision-maker. Specifically, we examine the functioning of an internal market for Fuel Efficiency Credits (FEC) with organized trading and FCE pricing between the different divisions of the manufacturing firm. A testbed experimental strategy is used to assess the reliability of an underlying theoretical model of how such a market will operate and the effects of this market institution on the firm's production, profits and overall fuel-efficiency. The experiments establish "proof of principle" that the internal market designed in accord with the theory produces high efficiency levels and increased profitability. Furthermore, the testbed demonstrates the property of "design consistency" in the sense that the theory of behavior that underlies the theory is observed in the decision choices at the individual division level. The experimental evidence presented in Section 5 suggests that high efficiency levels are attained, relatively easy adaptation and learning on the part of subjects is observed, and that the results are robust to miscalculations and poor performance of individual agents. The vehicle-manufacturer's performance, as measured by vehicle production, and profits, is substantially enhanced through the decentralized decision-making process that is consistent with the CAFE standard regulation, compared to alternative administrative responses available in the absence of an internal market for FEC.

The technology used for the experiments in this paper can be modified to account for additional complexities or adapted to address other issues or policy proposals concerning the automobile industry. For instance, Ellerman, Jacoby and Zimmerman (2006) consider the problem of integrating the CAFE program with a cap-and-trade system aimed at mitigating greenhouse gas emissions using some form of tradable instrument related to vehicle characteristics, such as fuel economy. The theoretical framework and the experimental strategy implemented in this paper can be easily extended to study this possibility. In addition, the theory underlying our work supports a natural generalization of regulatory policy to the case in which fuel efficiency credit trading between firms is allowed. In this context, there would be a single FEC traded in an open market among firms, with production and use being essentially analogous as in this paper. In the simplest case of a two-firm example, the implication would be as if firm A contracted with firm B for the production of vehicles; the vehicles produced by firm B would not be used in applying the CAFE standard to firm B but the vehicles would be used when applying the CAFE standard to firm A. We leaver these possible extensions of our work for further research.

TABLES AND FIGURES

Table 1 - Parameters of Experimental Design A

Subject ID	*s* (size of vehicle)	**MPG**	**Equilibrium production of vehicles**	**FEC bought (sold) in equilibrium**
1	1.5	26.7	43	(287)
2	15	2.7	13	242
3	8.75	4.6	10	167
4	1.75	22.9	28	81
5	9	4.4	11	171
6	9.75	4.1	12	183
7	1.5	26.7	43	(287)
8	9.5	4.2	11	179
9	1.5	26.7	43	(287)
10	2	20.0	20	0

Table 2 - Parameters of Experimental Design B

Subject ID	*s* (size of vehicle)	**Original MPG**	**Alternative MPG choices**			**Equilibrium MPG**	**Equilibrium production of vehicles**	**FEC bought (sold) in equilibrium**
1	1.5	26.7	27.9	28.9	29.9	28.9	36	(317)
2	15	2.7	2.9	3.9	4.9	3.9	17	267
3	8.75	4.6	5.0	6.0	7.0	6.0	15	208
4	1.75	22.9	24.0	25.0	26.9	25.0	27	(133)
5	9	4.4	4.9	5.9	6.9	5.9	15	211
6	9.75	4.1	4.5	5.5	6.5	5.5	15	222
7	1.5	26.7	27.9	28.9	29.9	28.9	36	(317)
8	9.5	4.2	4.6	5.6	6.6	5.6	15	218
9	1.5	26.7	27.9	28.9	29.9	28.9	36	(317)
10	2	20.0	21.1	22.1	23.1	22.1	22	(44)

Figure 1: Equilibrium in the FEC market for the two experimental designs

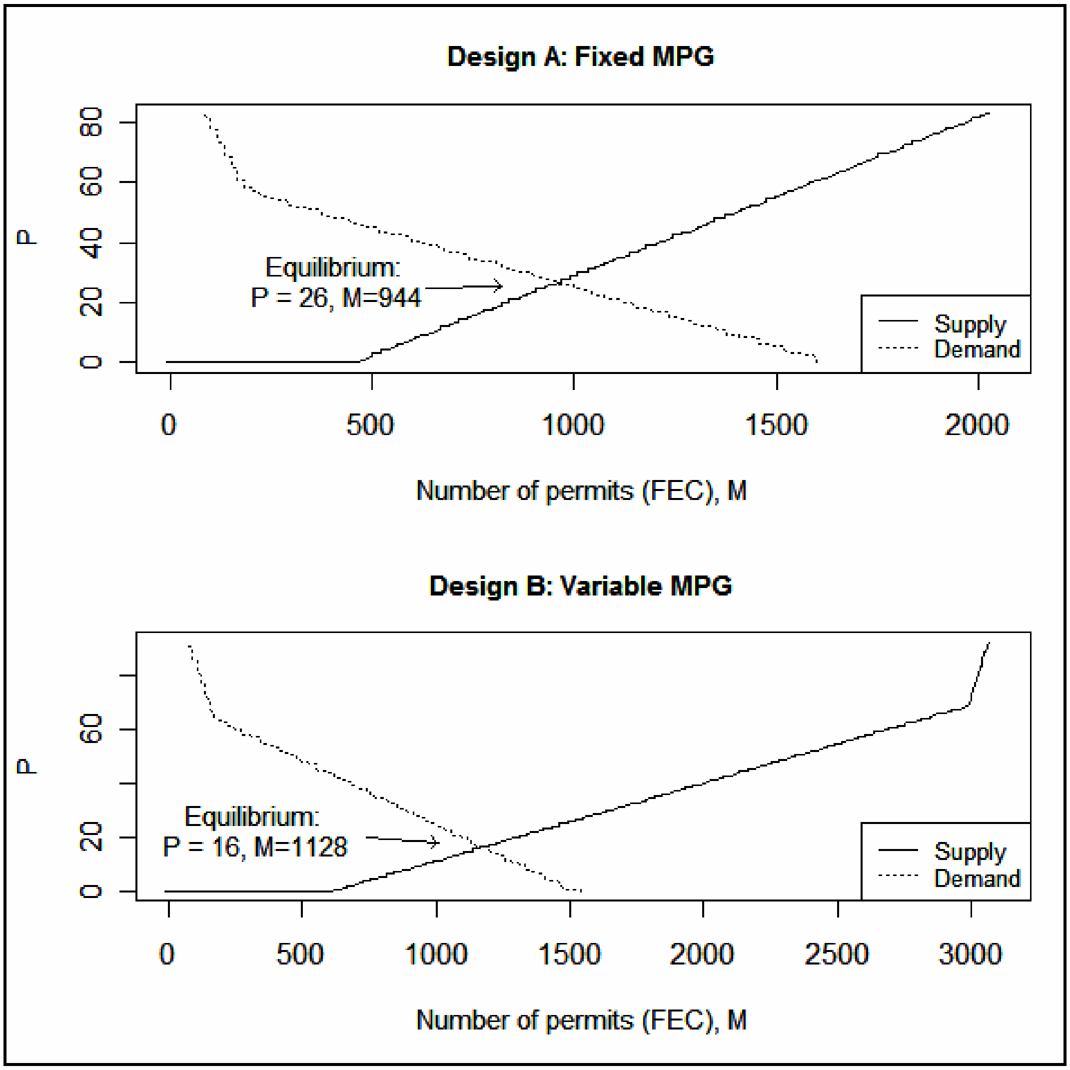


Table 3 – Comparison of production, profit and fuel-efficiency levels: Alternative baseline scenarios

	Centralized optimum	**No CAFE regulation**	**Administrative response (proportional rescaling)**
Design A – Fixed mpg			
Production (number of vehicles)	234	200	128
Profits (experiment money)	42,473	60,250	33,483
Fuel-efficiency (mpg)	20.11	14.29	20.07
Design B – Variable mpg			
Production (number of vehicles)	233	200	142
Profits (experiment money)	48,992	60,250	40,612
Fuel-efficiency (mpg)	20.03	14.29	21.71

Figure 2 – Trade prices in the FEC market
Design A: Fixed mpg

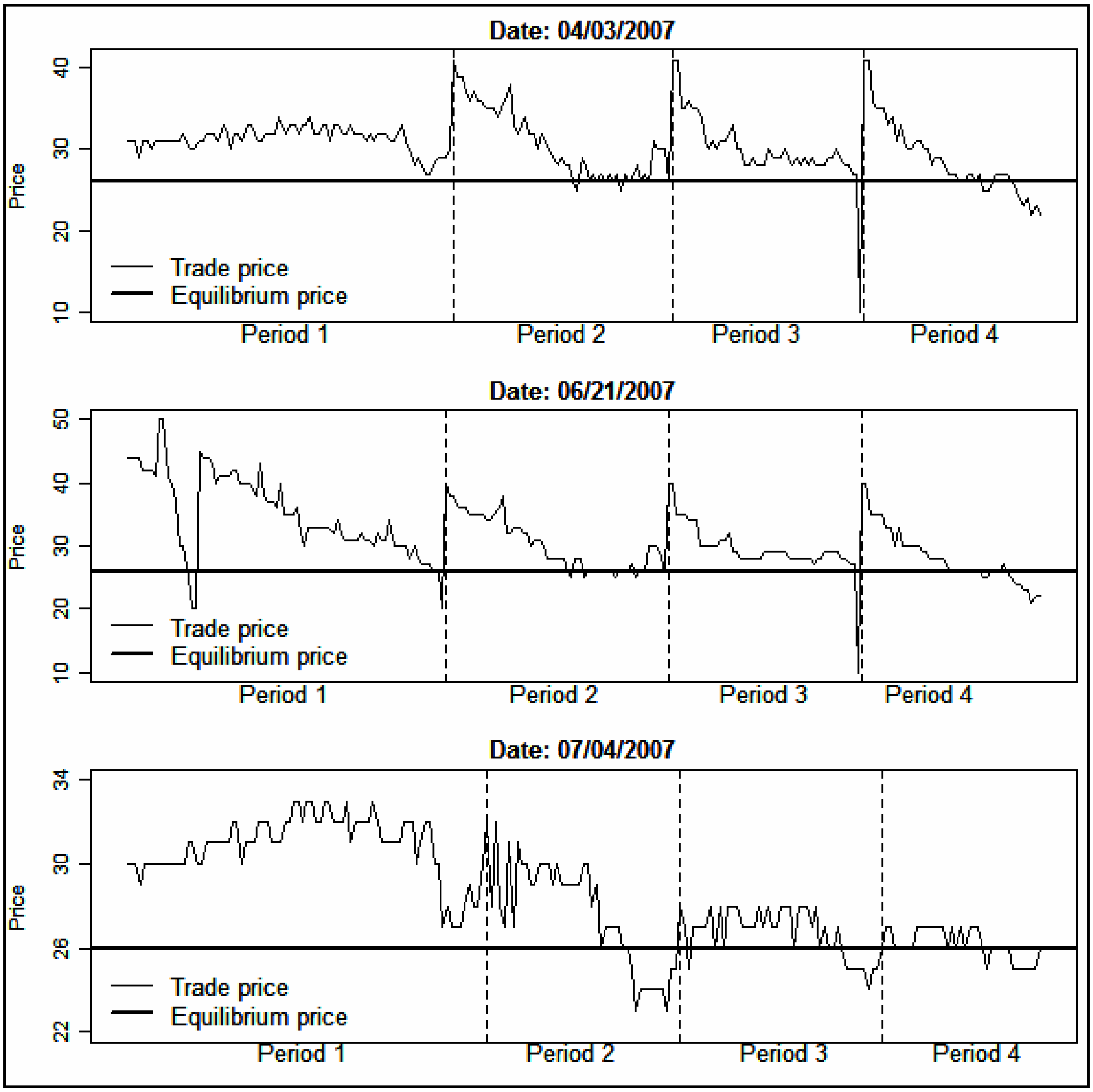


Figure 3 – Trade prices in the FEC market
Design B: Variable mpg

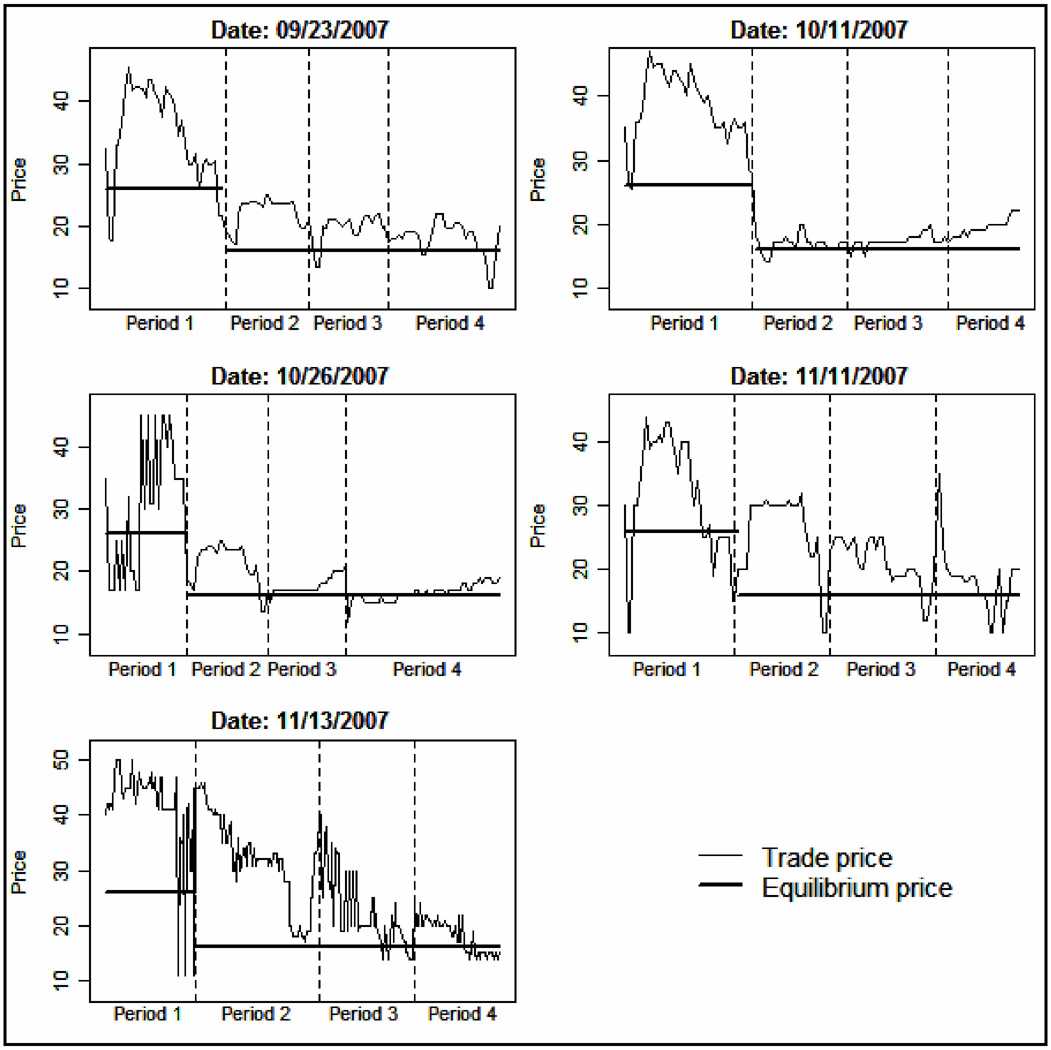


Table 4 – Parameter estimates of the regression of price-equilibrium price on transaction times (standard deviations in parenthesis)

	Design A	**Design B**
Transaction time	-0.04^{***} (0.01)	-0.07^{***} (0.01)
Session 1	8.62^{***} (0.35)	9.39^{***} (0.64)
Session 2	9.54^{***} (0.35)	10.40^{***} (0.63)
Session 3	6.29^{***} (0.34)	7.28^{***} (0.63)
Session 4		8.96^{***} (0.65)
Session 5		18.15^{***} (0.73)
Adjusted R^2	0.65	0.62
F-Statistic	302^{***}	150^{***}
N	666	757

Significance levels: *** 0.01, ** 0.05, *0.1.

Figure 4 – Choice of mpg value by subject and by period, Design B

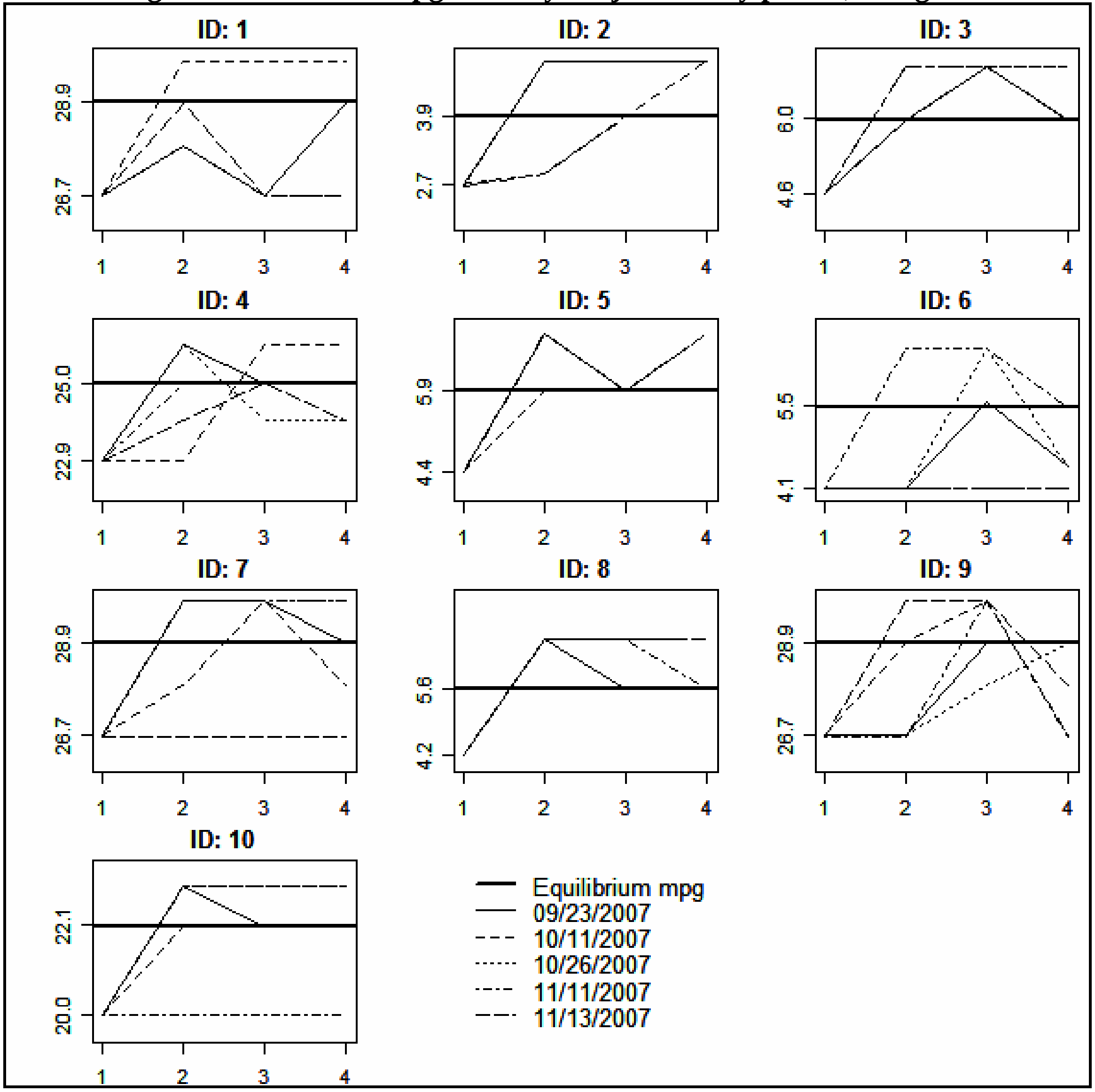
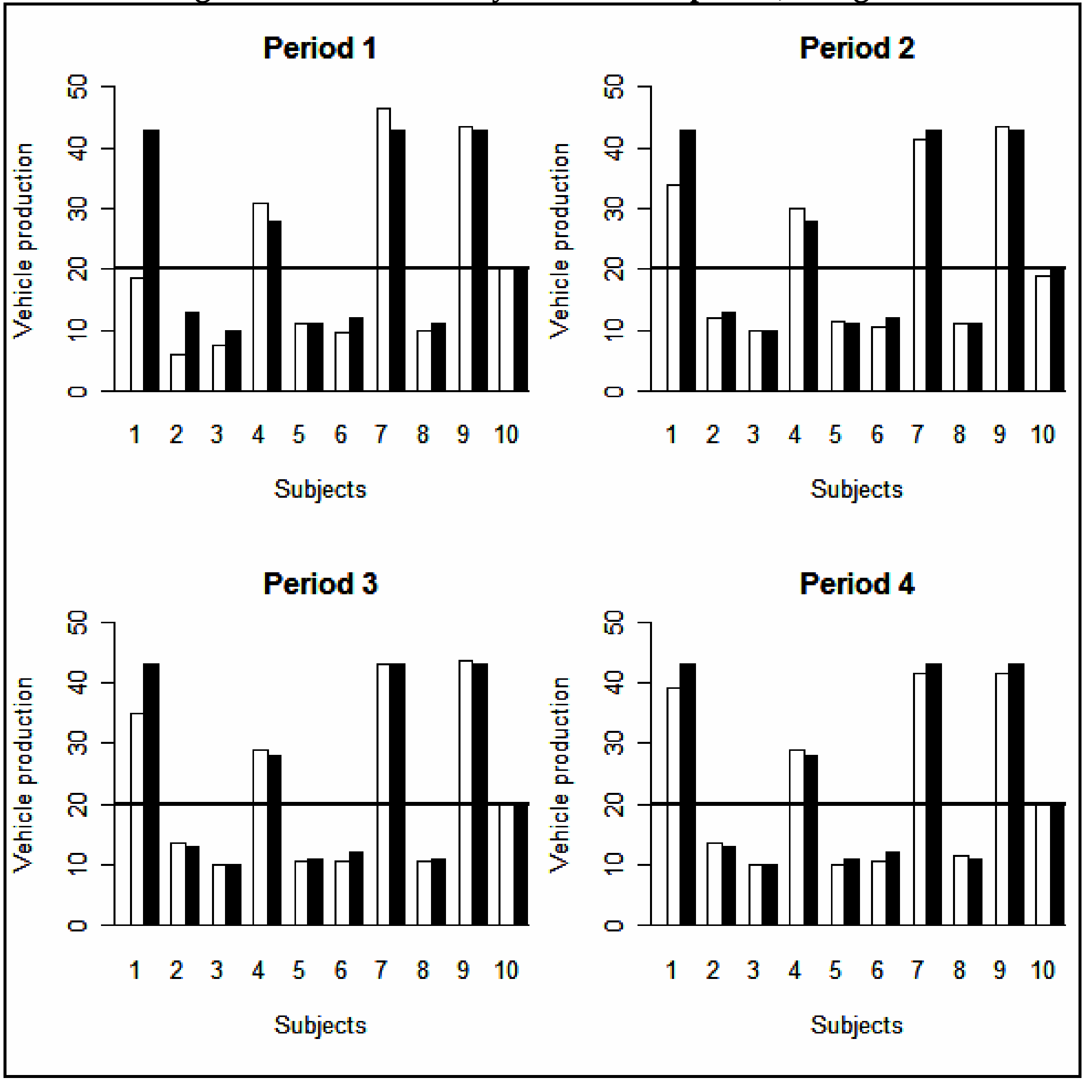


Table 5 – FEC traded, as percentage of equilibrium quantities

	Period 1	Period 2	Period 3	Period 4	All periods*
Design A – Fixed mpg					
04/03/2007	88.77	96.08	90.15	95.02	92.51 (3.59)
06/21/2007	83.58	99.79	98.83	95.23	94.36 (7.45)
07/04/2007	88.61	92.01	92.49	94.44	91.89 (2.43)
Design B – Variable mpg					
09/23/2007	105.97	85.49	97.31	91.00	94.94 (7.62)
10/11/2007	90.43	87.59	93.35	92.11	90.87 (2.49)
10/26/2007	91.37	92.45	91.47	86.52	90.45 (2.67)
11/11/2007	95.87	80.76	103.28	77.75	89.41 (12.18)
11/13/2007	113.98	88.12	95.30	89.89	96.82 (11.84)

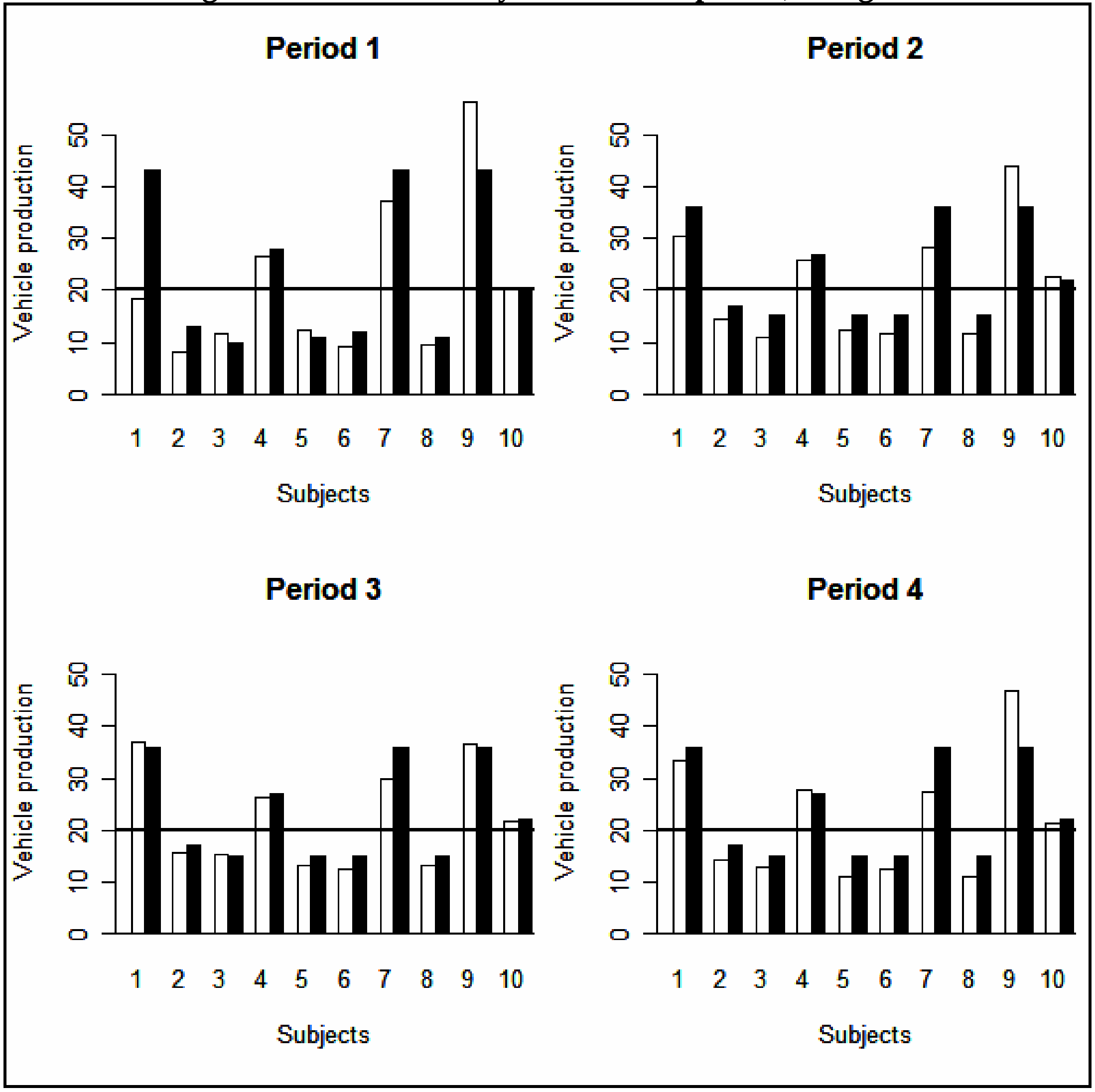
* Sample standard deviations reported in parenthesis.

Figure 5 – Production by division and period, Design A



Note: White bars represent experiment output and black bars represent the equilibrium production. The horizontal line indicates the equilibrium production without the CAFE standard regulation.

Figure 6 – Production by division and period, Design B



Note: White bars represent experiment output and black bars represent the equilibrium production. The horizontal line indicates the equilibrium production without the CAFE standard regulation.

Table 6 – Two-sample t-tests for the absolute value of the difference between the equilibrium and the per-period experimental output under both designs[1]

Subject	Estimated mean difference between equilibrium and per-period observed production		p-value of the two-sample t-test[2]
	Design A	Design B	
1	9.3	14.4	0.50
2	3.8	1.7	0.55
3	0.75	5.0	0.02
4	0.75	2.78	0.05
5	1.0	2.9	0.15
6	1.3	3.6	0.15
7	2.3	8.1	0.03
8	0.25	3.89	0.03
9	2.8	14.6	0.01
10	0.25	2.22	0.08

[1] There are 12 observations for each division under Design A, and 20 under Design B.

[2] Two-sided.

Table 7 – Estimates of the Poisson regression (standard deviations in parenthesis)

	Specification 1	**Specification 2**
Intercept	1.69*** (0.48)	0.78 (0.5)
Period	-0.38*** (0.07)	-0.38*** (0.07)
Price	-0.01 (0.01)	-0.01 (0.01)
Design B	0.79*** (0.11)	0.79*** (0.11)
Fuel Efficiency		
Dummy	0.89*** (0.09)	
Scale		0.24*** (0.02)
Null Deviance	882.21	882.21
Residual Deviance	675.42	606.31
AIC	1014	945.2
N	320	320

Significance levels: *** 0.01, ** 0.05, *0.1.

Table 8 – Efficiency levels per period, Designs A and B

Experiment	Efficiency levels (%)			
	Period 1	Period 2	Period 3	Period 4
Design A – Fixed mpg				
04/03/2007	86.60	94.31	95.23	99.11
06/21/2007	91.86	96.17	96.48	99.79
07/04/2007	84.54	97.16	98.19	99.87
Design B – Variable mpg				
09/23/2007	91.17	92.95	91.06	93.47
10/11/2007	69.87	87.91	95.62	85.78
10/26/2007	84.9	90.8	93.1	94.5
11/11/2007	84.15	81.29	84.09	80.73
11/13/2007	76.57	87.64	93.71	91.61

Figure 7 – Relative efficiency levels under Designs A and B

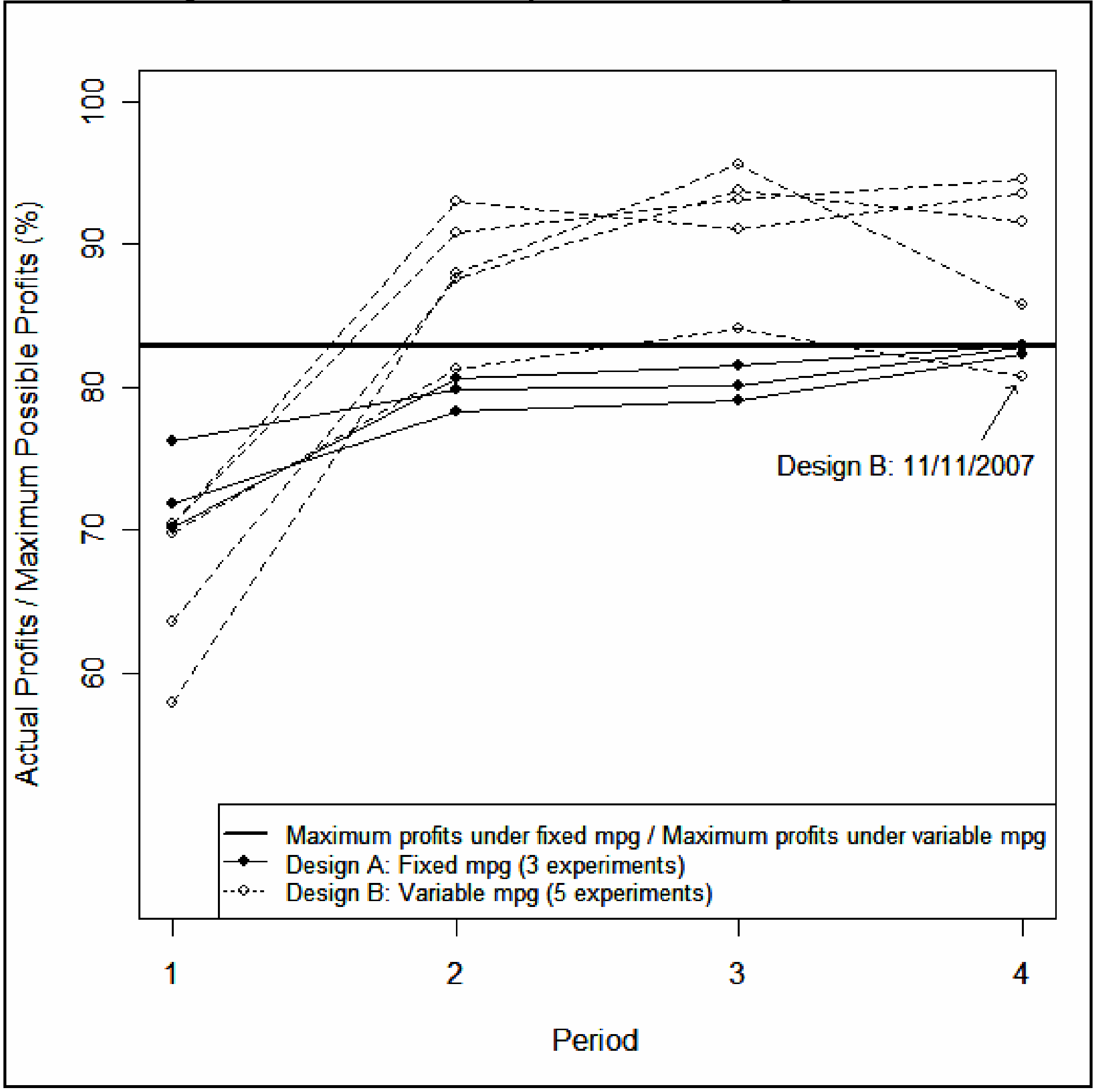


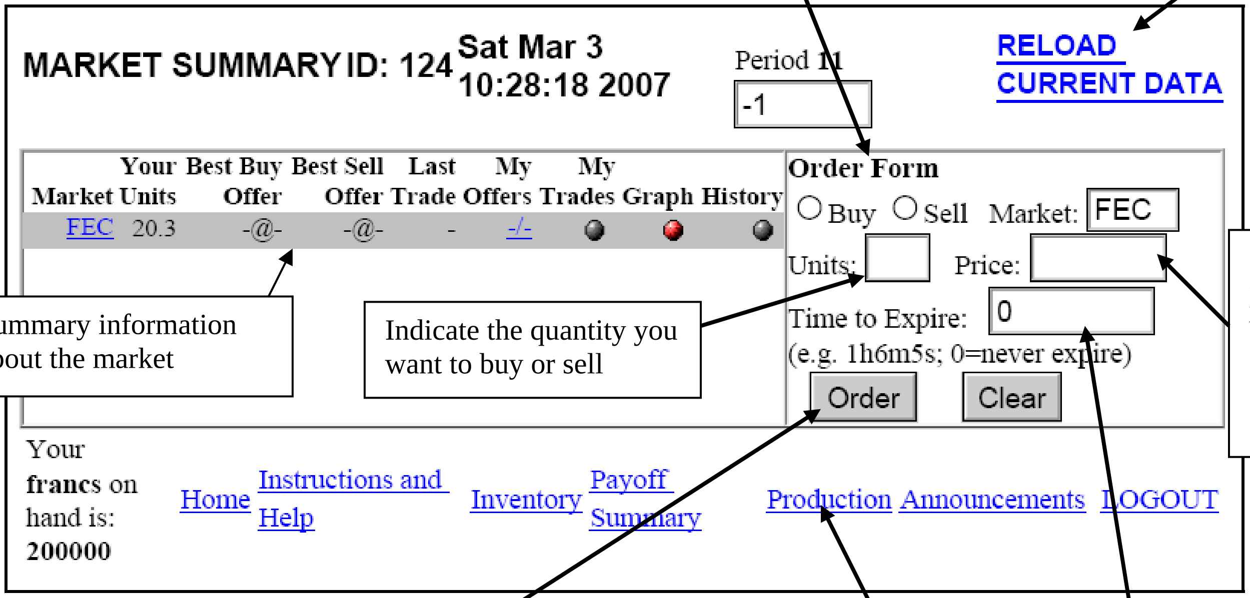
Table 9– System-wide production, profit and fuel-efficiency levels under designs A and B[*]

	Design A	**Design B**
Production (number of vehicles)	221 (22.41)	220 (19.43)
Profits (experiment money)	40,706 (2,167.37)	43,201 (5,401.57)
Fuel-efficiency (mpg)	20.08 (0.42)	19.56 (1.43)

[*] Sample standard deviations reported in parenthesis.

Appendix I – Computer Screen Guide

FEC market



MARKET SUMMARY ID: 124 Sat Mar 3 10:28:18 2007

Period 11

-1

RELOAD CURRENT DATA

Market	Your Units	Best Buy Offer	Best Sell Offer	Last Trade	My Offers	My Trades	Graph	History
FEC	20.3	-@-	-@-	-	-/-	●	●	●

Order Form

○ Buy ○ Sell Market: FEC

Units: Price:

Time to Expire: 0

(e.g. 1h6m5s; 0=never expire)

Order Clear

Your **francs** on hand is: **200000**

Home | Instructions and Help | Inventory | Payoff Summary | Production | Announcements | LOGOUT

Indicate if you want to buy or sell FECs

Press **RELOAD** to actualize your screen each time you change any input

Summary information about the market

Indicate the quantity you want to buy or sell

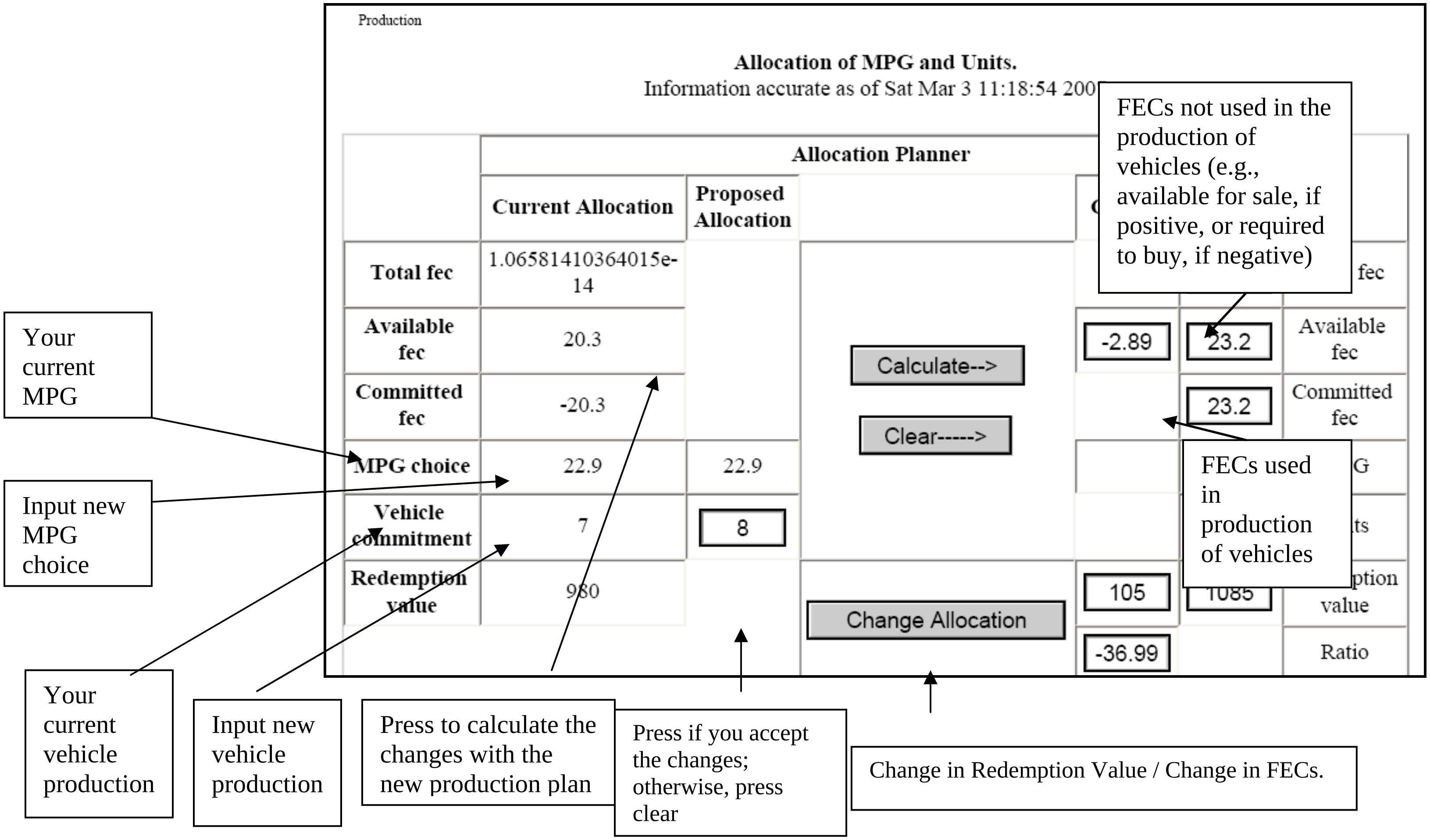
Indicate the price you want to pay or receive for **each** FEC

Press to put your order in the market. Otherwise, press clear

Press to see your production plan

Time remaining to make transactions

Production screen



Production

Allocation of MPG and Units.

Information accurate as of Sat Mar 3 11:18:54 200

	Allocation Planner					
	Current Allocation	Proposed Allocation		C		
Total fec	1.06581410364015e-14					fec
Available fec	20.3		Calculate-->	-2.89	23.2	Available fec
Committed fec	-20.3		Clear----->		23.2	Committed fec
MPG choice	22.9	22.9				G
Vehicle commitment	7	8				ts
Redemption value	980		Change Allocation	105	1085	ption value
				-36.99		Ratio

FECs not used in the production of vehicles (e.g., available for sale, if positive, or required to buy, if negative)

Your current MPG

Input new MPG choice

FECs used in production of vehicles

Your current vehicle production

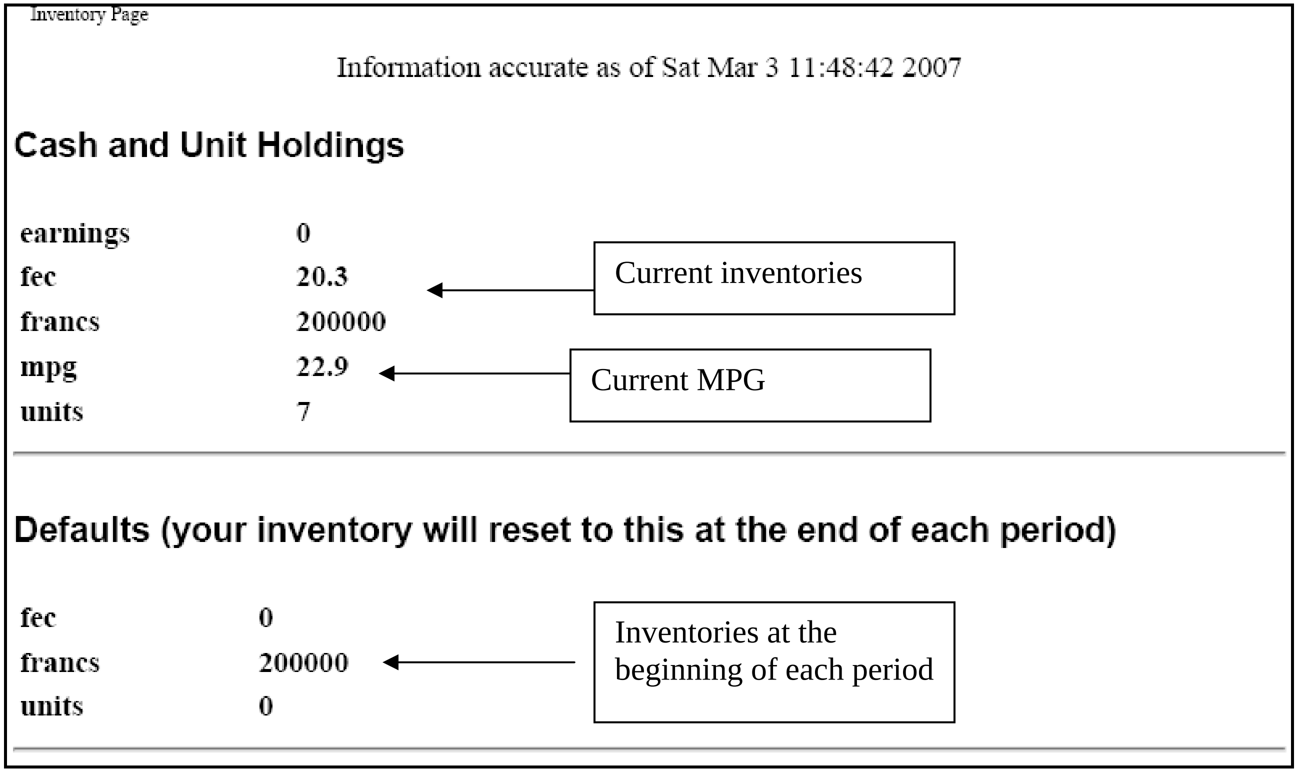
Input new vehicle production

Press to calculate the changes with the new production plan

Press if you accept the changes; otherwise, press clear

Change in Redemption Value / Change in FECs.

Inventory screen



Inventory Page

Information accurate as of Sat Mar 3 11:48:42 2007

Cash and Unit Holdings

earnings	**0**
fec	**20.3**
francs	**200000**
mpg	**22.9**
units	**7**

Current inventories

Current MPG

Defaults (your inventory will reset to this at the end of each period)

fec	**0**
francs	**200000**
units	**0**

Inventories at the beginning of each period

Appendix II – Instructions

You are about to participate in a special market process that will consist of a number of independent periods or “days”. If you follow the instructions carefully and make good decisions, you may earn a considerable amount of money. You will be paid in EC 11 credits at the end of the experiment. The currency used in the experiment is called francs, but your credits will be computed in US Dollars, at an exchange rate of ________________

Please do not talk or in any way communicate with other participants. If you have a question or problem, please raise your hand and one of the experimenters will come to you.

You will find attached a payoff sheet that will describe the value to you of your decisions, a key to the functions used on the computer and a record of earnings sheet.

GENERAL INSTRUCTIONS

In this experiment, you are placed in a position of a vehicle manufacturer who operates under specific economic and regulatory constraints.

Each period, the value to you of producing “vehicle” units are contained in your **redemption value table** found attached to these instructions. Think of **redemption values** as the amount of profit you can make each period from the sale of the units you produce that period.

When producing your vehicles, you will deal with a regulation called “Corporate Average Fuel Economy” (CAFE). This means that your decisions will be closely aligned with a special market for fuel efficiency credits (FEC).

The impact of the regulation depends on the fuel efficiency of your vehicle, measured in miles per gallon (mpg). The mpg of your vehicle determines what you must do or what you are able to do in the FEC market. You will be originally assigned a certain mpg that you will find on your redemption value table and in your computer screen.

- If the mpg of your vehicle is **BELOW** 20, then you are required to deposit FEC with each vehicle you produce. If you do not have the FEC required by the amount that you want to produce, then you must buy them on the FEC market. For each vehicle you produce you will need FEC equal to 20 minus the mpg of your vehicle.

- If the mpg of your vehicle is **ABOVE** 20, then you receive new FEC with each additional vehicle produced. The FEC you receive can then be sold in the FEC market for profit. For each vehicle you produce, you will receive FEC equal to the mpg of your vehicle minus 20.

- If you buy FEC you spend francs and if you sell FEC you receive francs. You are given a loan of 200,000 francs each period. This loan must be repaid at the end of the experiment.

- **PROFIT DETERMINATION, REDEMPTION VALUE TABLES AND EARNINGS**

The information regarding the redemption values and the FEC requirements from the production of vehicles is given in your Redemption Value Table. Consider the following two cases:

CASE ONE: The mpg of your vehicle is BELOW 20.

If the mpg of your vehicle is **BELOW** 20 then your profit is:

Profit = **Value received from vehicles produced – cost of FEC for the production of the vehicles**.

EXAMPLE 1) **Your mpg is below 20, so you must buy and use FEC with each vehicle unit produced.** Suppose your Redemption Value Table is like Table 1, and you have produced 4 units and have an MPG of 2.67.

Column (C), labeled “unit redemption value”, gives you the INCREMENTAL redemption value for each unit produced (e.g., 1200 francs for the 4th unit produce and 1125 for the 5th unit).

Column (D), labeled “total of redemption values”, gives the SUM of the INCREMENTAL redemption values of the units you produce (e.g. 5250 francs if you produce 4 units and 6375 if 5). Column (E), labeled “FEC REQUIRED per unit”, indicates the number of FCE you need to buy for each vehicle you produce: 17.33.

Column (G) gives you the redemption value per FEC obtained per unit of vehicle produced.

Table 1 – Redemption values

(A) Unit	**(B)** Your MPG	**(C)** Unit (incremental) redemption value	**(D)** Total of redemption values	**(E)** FEC REQUIRED per unit: **20 - (B)**	**(F)** Total FEC REQUIRED: **(E)*(A)**	**(G)** Redemption value per FEC REQUIRED by unit produced: **(C) / (E)**
1	2.67	1425	1425	20-2.67=17.33	17.33 *1=17.33	1425/17.33 = 82.23
2	2.67	1350	2775	20-2.67=17.33	17.33 * 2 =34.66	1350/17.33 = 77.90
3	2.67	1275	4050	20-2.67=17.33	17.33 * 3 = 51.99	1275/17.33 = 73.57
4	2.67	1200	5250	20-2.67=17.33	17.33 * 4 =69.32	1200/17.33 = 69.24
5	2.67	1125	6375	20-2.67=17.33	86.65	1125 / 17.33 =64.92
…	2.67	…	...	20-2.67=17.33	....	...
20	2.67	0	14250	20-2.67=17.33	346.6	0/17.33 = 0
21	2.67	-75	14175	20-2.67=17.33	363.93	-75 / 17/33 = -4.33
...	..	...		...	...	...

So long as you pay less for the FEC needed to produce an incremental unit that the incremental redemption value for the unit, the unit is profitable for you. Notice that the INCREMENTAL redemption values are positive up to several units and then can become negative. **If the required FEC for the unit are acquired at a per unit price below the figure in column (G), then the FEC purchase together with the unit production is profitable.**

CASE TWO: The mpg of your vehicle is ABOVE 20.

If the MPG of your vehicle is **ABOVE** 20 then your profit is:

Profit = Value received from vehicles produced + revenue received from the sale of FEC

EXAMPLE 2) Your vehicle mpg is above 20, so you obtain FEC along with each vehicle unit produced. You can sell the FEC you obtain. Suppose your redemption value table is like Table 2, and you have produced 4 units and have an mpg of 22.9.

Column (C), labeled “unit redemption value”, gives you the INCREMENTAL redemption value for each unit produced (e.g., -8.75 francs for the 4th unit produce and -17.5 for the 5th unit). It is as if you are producing the vehicles at a loss (not including possible sale of the FEC obtained).

Column (D), labeled “total of redemption values”, gives the SUM of the INCREMENTAL redemption values of the units you produce (e.g. 315 francs if you produce 4 units and 297.5 if 5).

Column (E), labeled “FEC OBTAINED per unit”, indicates the number of FEC you obtain from each incremental vehicle you produce: 2.9.

Column (F), labeled Total FEC OBTAINED is the sum of all or the FEC obtained from all incremental units.

Column (G) gives you the redemption value per FEC obtained per unit of vehicle produced.

Table 2 – Redemption values

(A) Unit	**(B)** Your MPG	**(C)** Unit (incremental) redemption value	**(D)** Total of redemption values	**(E)** FEC OBTAINED per incremental unit: **(B) - 20**	**(F)** Total FEC OBTAINED **(E)*(A)**	**(G)** Redemption value per FEC OBTAINED by unit produced: **(C) / (E)**
1	22.9	166.25	166.25	22.9-20=2.9	2.9 *1=2.9	166.25/2.9 = 57.33
2	22.9	157.5	323.75	22.9-20=2.9	2.9 * 2 =5.8	157.5/2.9 = 54.31
3	22.9	0	323.75	22.9-20=2.9	2.9 * 3 = 8.7	0/2.9 = 0
4	22.9	-8.75	315	22.9-20=2.9	2.4 * 4 =11.6	-8.75/2.9 = -3.02
5	22.9	-17.5	297.5	22.9-20=2.9	2.9 * 5 =14.5	-17.5/2.9 = -6.03
6	22.9	-26.25	271.25	22.9-20=2.9	2.9*6=17.4	26.25/2.9 = -9.05
..,	..,	..,	..,	..,	..,	…
10	22.9	-61.25	57.15	22.9-20=2.9	2.9*10=29	-61.25/2.9 = -21.12
11	22.9	-70	-12.85	22.9–20=2.9	2.9 * 11=31.9	-70/2.9 = -24.14
…	…	…	…	…	…	..

.

The fact that the incremental redemption values are negative means that producing the unit will reduce your profit unless the loss from production is offset by the gain in revenue from the sale of FEC. Column (G) will help you in making this calculation. It can be viewed as the cost to you of obtaining incremental FEC. For example, if you are producing 4 vehicles, the additional FEC you obtain from producing the 5th vehicle will cost you 6.03 per FEC obtained. **If the prices received for the FEC obtained by the production of the unit are on average below the figure in column (G), then the production together with the sale of the FEC is profitable.**

CHANGING YOUR MPG PERFORMANCE:

In the first period of the experiment, you will have to produce vehicles with the mpg value that is originally assigned to you. In the following periods, you can choose to change the mpg of the vehicles you produce. Changing your mpg will affect the values you will receive for the vehicles produced and the FEC you will sell or buy in the FCE market. You can choose the mpg of the vehicles you produce at any time during these periods, but will have to produce only one type of car

–defined by its mpg - in each period. In order to choose your desired mpg level, you are given a payoff sheet for different possible mpg values.

Unit (incremental) and total redemption values for alternative mpg performances								
	Your current mpg		Alternative mpg values					
Units produced	mpg=26.7		Mpg=27.87		mpg=28.87		mpg=29.87	
	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
1	146	146	141	141	130	130	112	112
2	139	285	134	275	123	253	105	217
3	131	416	126	402	115	368	97	314
4	124	540	119	521	108	476	90	404
…	…	…	…	…	…	…	…	…

Earnings record sheet

Your earnings during the periods are the differences between the redemption values you receive for units and the costs or receipts that you derive from the FEC market. The record sheet will help you compute your earnings each period. Your end of period earnings are calculated using the total redemption value of the vehicles produced and substracting (adding) the value of your purchases (sales) of FEC.

RECORD YOUR EARNINGS AFTER EACH ROUND OF THE EXPERIMENT. Your end of period earnings will be listed in the **PAYOFF SUMMARY** screen of your computer.

Table 3 - Record of earnings sheet

PERIOD 1	**number**	**TOTAL OF REDEMPTION VALUES**
vehicle commitment	**(a)**	**(c)**
Initial francs	200,000	
final francs	**(b)**	
CHANGE of francs		**(d)**
TOTAL EARNINGS		**(c) - (d)**

Input the number of cars you plan to produce in the period

Input the redemption values of the cars you plan to produce

Difference between 200,000 and your final amount of francs (recorded in cell b).

Input the amount of francs you have at the end of the period

Notice: (d) is positive if buying FEC and (d) is negative if selling FEC, so use subtraction in both cases.

Appendix III – Redemption values tables

ID: 1, 7, 9

	Total Value and Unit (marginal) Value of Different Vehicles										
Units	**MPG=26.67**			**MPG=27.87**			**MPG=28.87**			**MPG=29.87**	
	Total value	**UNIT**		**TOTAL**	**UNIT**		**TOTAL**	**UNIT**		**TOTAL**	**UNIT**
1	146	146		141	141		130	130		112	112
2	285	139		275	134		253	123		217	105
3	416	131		402	126		368	115		314	97
4	540	124		521	119		476	108		404	90
5	656	116		632	111		576	100		486	82
6	765	109		736	104		668	93		560	75
7	866	101		833	96		753	85		627	67
8	960	94		922	89		831	78		687	60
9	1046	86		1003	81		901	70		739	52
10	1125	79		1077	74		964	63		784	45
11	1196	71		1144	66		1019	55		821	37
12	1260	64		1203	59		1067	48		851	30
13	1316	56		1254	51		1107	40		873	22
14	1365	49		1298	44		1139	33		887	15
15	1406	41		1334	36		1164	25		894	7
16	1440	34		1363	29		1182	18		894	0
17	1466	26		1385	21		1192	10		886	-8
18	1485	19		1399	14		1195	3		871	-15
19	1496	11		1405	6		1190	-5		848	-23
20	1500	4		1404	-1		1178	-12		818	-30
21	1496	-4		1396	-9		1158	-20		780	-38
22	1485	-11		1380	-16		1130	-27		734	-45
23	1466	-19		1356	-24		1095	-35		681	-53
24	1440	-26		1325	-31		1053	-42		621	-60
25	1406	-34		1286	-39		1003	-50		553	-68
26	1365	-41		1240	-46		946	-57		478	-75
27	1316	-49		1187	-54		881	-65		395	-83
28	1260	-56		1126	-61		809	-72		305	-90
29	1196	-64		1057	-69		729	-80		207	-98
30	1125	-71		981	-76		641	-87		101	-105
31	1046	-79		898	-84		546	-95		-12	-113
32	960	-86		807	-91		444	-102		-132	-120
33	866	-94		708	-99		334	-110		-260	-128
34	765	-101		602	-106		217	-117		-395	-135
35	656	-109		489	-114		92	-125		-538	-143
36	540	-116		368	-121		-40	-132		-688	-150
37	416	-124		239	-129		-180	-140		-846	-158
38	285	-131		103	-136		-328	-147		-1012	-165
39	146	-139		-41	-144		-482	-155		-1185	-173
40	0	-146		-192	-151		-645	-162		-1365	-180
41	-154	-154		-350	-159		-815	-170		-1553	-188
42	-315	-161		-516	-166		-992	-177		-1748	-195
43	-484	-169		-690	-174		-1177	-185		-1951	-203
44	-660	-176		-871	-181		-1369	-192		-2161	-210
45	-844	-184		-1059	-189		-1569	-200		-2379	-218

ID: 2

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=2.67			MPG=2.91			MPG=3.91			MPG=4.91	
	TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT
1	1463	1463		1462	1462		1453	1453		1432	1432
2	2850	1388		2849	1387		2832	1378		2790	1357
3	4163	1313		4161	1312		4135	1303		4072	1282
4	5400	1238		5399	1237		5363	1228		5280	1207
5	6563	1163		6561	1162		6517	1153		6412	1132
6	7650	1088		7648	1087		7595	1078		7470	1057
7	8663	1013		8660	1012		8598	1003		8452	982
8	9600	938		9597	937		9527	928		9360	907
9	10463	863		10459	862		10380	853		10192	832
10	11250	788		11247	787		11159	778		10950	757
11	11963	713		11959	712		11862	703		11632	682
12	12600	638		12596	637		12490	628		12240	607
13	13163	563		13158	562		13044	553		12772	532
14	13650	488		13645	487		13522	478		13230	457
15	14063	413		14057	412		13925	403		13612	382
16	14400	338		14394	337		14254	328		13919	307
17	14663	263		14657	262		14507	253		14152	232
18	14850	188		14844	187		14685	178		14309	157
19	14963	113		14956	112		14789	103		14392	82
20	15000	38		14993	37		14817	28		14399	7
21	14963	-38		14955	-38		14770	-47		14332	-68
22	14850	-113		14842	-113		14649	-122		14189	-143
23	14663	-188		14655	-188		14452	-197		13972	-218
24	14400	-263		14392	-263		14181	-272		13679	-293
25	14063	-338		14054	-338		13834	-347		13312	-368
26	13650	-413		13641	-413		13412	-422		12869	-443
27	13163	-488		13153	-488		12916	-497		12352	-518
28	12600	-563		12590	-563		12344	-572		11759	-593
29	11963	-638		11953	-638		11697	-647		11092	-668
30	11250	-713		11240	-713		10976	-722		10349	-743
31	10463	-788		10452	-788		10179	-797		9531	-818
32	9600	-863		9589	-863		9307	-872		8639	-893
33	8663	-938		8651	-938		8361	-947		7671	-968
34	7650	-1013		7638	-1013		7339	-1022		6629	-1043
35	6563	-1088		6550	-1088		6242	-1097		5511	-1118
36	5400	-1163		5388	-1163		5071	-1172		4319	-1193
37	4163	-1238		4150	-1238		3824	-1247		3051	-1268
38	2850	-1313		2837	-1313		2503	-1322		1709	-1343
39	1463	-1388		1449	-1388		1106	-1397		291	-1418
40	0	-1463		-14	-1463		-366	-1472		-1201	-1493
41	-1538	-1538		-1552	-1538		-1912	-1547		-2769	-1568
42	-3150	-1613		-3164	-1613		-3534	-1622		-4411	-1643
43	-4838	-1688		-4852	-1688		-5231	-1697		-6129	-1718
44	-6600	-1763		-6615	-1763		-7002	-1772		-7921	-1793
45	-8438	-1838		-8453	-1838		-8849	-1847		-9789	-1868

ID: 3

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=4.57			MPG=4.99			MPG=5.99			MPG=6.99	
	TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT
1	853	853		852	852		842	842		822	822
2	1663	809		1661	808		1640	798		1600	778
3	2428	766		2425	765		2394	754		2334	734
4	3150	722		3146	721		3105	711		3025	691
5	3828	678		3823	677		3772	667		3671	647
6	4463	634		4457	633		4395	623		4275	603
7	5053	591		5046	590		4974	579		4834	559
8	5600	547		5592	546		5510	536		5349	516
9	6103	503		6095	502		6001	492		5821	472
10	6563	459		6553	458		6450	448		6249	428
11	6978	416		6968	415		6854	404		6634	384
12	7350	372		7339	371		7214	361		6974	341
13	7678	328		7666	327		7531	317		7271	297
14	7963	284		7949	283		7804	273		7524	253
15	8203	241		8189	240		8034	229		7733	209
16	8400	197		8385	196		8219	186		7899	166
17	8553	153		8537	152		8361	142		8021	122
18	8663	109		8645	108		8459	98		8099	78
19	8728	66		8710	65		8514	54		8133	34
20	8750	22		8731	21		8524	11		8123	-9
21	8728	-22		8708	-23		8491	-33		8070	-53
22	8663	-66		8642	-67		8414	-77		7973	-97
23	8553	-109		8531	-110		8293	-121		7833	-141
24	8400	-153		8377	-154		8129	-164		7648	-184
25	8203	-197		8179	-198		7921	-208		7420	-228
26	7963	-241		7938	-242		7669	-252		7148	-272
27	7678	-284		7653	-285		7373	-296		6832	-316
28	7350	-328		7323	-329		7034	-339		6473	-359
29	6978	-372		6951	-373		6651	-383		6070	-403
30	6563	-416		6534	-417		6224	-427		5623	-447
31	6103	-459		6074	-460		5753	-471		5132	-491
32	5600	-503		5570	-504		5239	-514		4597	-534
33	5053	-547		5022	-548		4680	-558		4019	-578
34	4463	-591		4430	-592		4078	-602		3397	-622
35	3828	-634		3795	-635		3433	-646		2732	-666
36	3150	-678		3116	-679		2743	-689		2022	-709
37	2428	-722		2393	-723		2010	-733		1269	-753
38	1663	-766		1626	-767		1233	-777		472	-797
39	853	-809		816	-810		413	-821		-369	-841
40	0	-853		-38	-854		-452	-864		-1253	-884
41	-897	-897		-936	-898		-1360	-908		-2181	-928
42	-1838	-941		-1877	-942		-2312	-952		-3153	-972
43	-2822	-984		-2863	-985		-3308	-996		-4169	-1016
44	-3850	-1028		-3892	-1029		-4347	-1039		-5228	-1059
45	-4922	-1072		-4965	-1073		-5430	-1083		-6332	-1103

ID: 4

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=22.86			MPG=23.98			MPG=24.98			MPG=25.98	
	TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT
1	171	171		166	166		154	154		136	136
2	333	162		323	157		300	146		262	127
3	486	153		472	149		437	137		381	118
4	630	144		612	140		565	128		490	109
5	766	136		743	131		685	119		591	101
6	893	127		865	122		796	111		682	92
7	1011	118		979	114		898	102		766	83
8	1120	109		1084	105		991	93		840	74
9	1221	101		1180	96		1075	84		906	66
10	1313	92		1267	87		1151	76		962	57
11	1396	83		1346	79		1218	67		1011	48
12	1470	74		1416	70		1276	58		1050	39
13	1536	66		1477	61		1326	49		1081	31
14	1593	57		1529	52		1366	41		1102	22
15	1641	48		1573	44		1398	32		1116	13
16	1680	39		1608	35		1421	23		1120	4
17	1711	31		1634	26		1436	14		1116	-4
18	1733	22		1651	17		1442	6		1102	-13
19	1746	13		1660	9		1439	-3		1081	-22
20	1750	4		1660	0		1427	-12		1050	-31
21	1746	-4		1651	-9		1406	-21		1011	-39
22	1733	-13		1633	-18		1377	-29		962	-48
23	1711	-22		1607	-26		1339	-38		906	-57
24	1680	-31		1572	-35		1292	-47		840	-66
25	1641	-39		1528	-44		1237	-56		766	-74
26	1593	-48		1475	-53		1172	-64		682	-83
27	1536	-57		1414	-61		1099	-73		591	-92
28	1470	-66		1344	-70		1018	-82		490	-101
29	1396	-74		1265	-79		927	-91		381	-109
30	1313	-83		1177	-88		828	-99		262	-118
31	1221	-92		1081	-96		720	-108		136	-127
32	1120	-101		976	-105		603	-117		0	-136
33	1011	-109		862	-114		477	-126		-144	-144
34	893	-118		739	-123		343	-134		-298	-153
35	766	-127		608	-131		200	-143		-459	-162
36	630	-136		468	-140		48	-152		-630	-171
37	486	-144		319	-149		-112	-161		-809	-179
38	333	-153		161	-158		-282	-169		-998	-188
39	171	-162		-5	-166		-460	-178		-1194	-197
40	0	-171		-180	-175		-646	-187		-1400	-206
41	-179	-179		-364	-184		-842	-196		-1614	-214
42	-368	-188		-557	-193		-1046	-204		-1838	-223
43	-564	-197		-758	-201		-1259	-213		-2069	-232
44	-770	-206		-968	-210		-1481	-222		-2310	-241
45	-984	-214		-1187	-219		-1712	-231		-2559	-249

ID: 5

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=4.44			MPG=4.85			MPG=5.85			MPG = 6.85	
	TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT
1	878	878		877	877		867	867		846	846
2	1710	833		1708	832		1688	822		1647	801
3	2498	788		2495	787		2465	777		2403	756
4	3240	743		3236	742		3197	732		3114	711
5	3938	698		3933	697		3884	687		3780	666
6	4590	653		4585	652		4525	642		4401	621
7	5198	608		5191	607		5122	597		4977	576
8	5760	563		5753	562		5674	552		5509	531
9	6278	518		6269	517		6181	507		5995	486
10	6750	473		6741	472		6642	462		6436	441
11	7178	428		7167	427		7059	417		6832	396
12	7560	383		7549	382		7431	372		7183	351
13	7898	338		7886	337		7758	327		7489	306
14	8190	293		8177	292		8039	282		7750	261
15	8438	248		8424	247		8276	237		7966	216
16	8640	203		8625	202		8468	192		8137	171
17	8798	158		8782	157		8615	147		8263	126
18	8910	113		8894	112		8716	102		8344	81
19	8978	68		8960	67		8773	57		8380	36
20	9000	23		8982	22		8785	12		8371	-9
21	8978	-23		8958	-23		8752	-33		8317	-54
22	8910	-68		8890	-68		8673	-78		8218	-99
23	8798	-113		8777	-113		8550	-123		8074	-144
24	8640	-158		8618	-158		8382	-168		7886	-189
25	8438	-203		8415	-203		8168	-213		7652	-234
26	8190	-248		8166	-248		7910	-258		7373	-279
27	7898	-293		7873	-293		7607	-303		7049	-324
28	7560	-338		7535	-338		7259	-348		6680	-369
29	7178	-383		7151	-383		6865	-393		6266	-414
30	6750	-428		6723	-428		6427	-438		5807	-459
31	6278	-473		6249	-473		5944	-483		5303	-504
32	5760	-518		5731	-518		5416	-528		4754	-549
33	5198	-563		5167	-563		4842	-573		4160	-594
34	4590	-608		4559	-608		4224	-618		3521	-639
35	3938	-653		3906	-653		3561	-663		2837	-684
36	3240	-698		3207	-698		2853	-708		2108	-729
37	2498	-743		2464	-743		2099	-753		1334	-774
38	1710	-788		1675	-788		1301	-798		515	-819
39	878	-833		842	-833		458	-843		-349	-864
40	0	-878		-36	-878		-430	-888		-1257	-909
41	-923	-923		-960	-923		-1364	-933		-2211	-954
42	-1890	-968		-1928	-968		-2342	-978		-3210	-999
43	-2903	-1013		-2942	-1013		-3365	-1023		-4254	-1044
44	-3960	-1058		-4000	-1058		-4433	-1068		-5343	-1089
45	-5063	-1103		-5103	-1103		-5547	-1113		-6477	-1134

ID: 6

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=4.10		MPG=4.47		MPG=5.47		MPG=6.47	
	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT
1	951	951	950	950	940	940	920	920
2	1853	902	1851	901	1832	891	1790	871
3	2706	853	2703	852	2674	843	2613	822
4	3510	804	3507	804	3468	794	3386	773
5	4266	756	4262	755	4213	745	4111	725
6	4973	707	4968	706	4910	696	4786	676
7	5631	658	5625	657	5557	648	5414	627
8	6240	609	6234	609	6156	599	5992	578
9	6801	561	6794	560	6706	550	6521	530
10	7313	512	7305	511	7208	501	7002	481
11	7776	463	7767	462	7660	453	7434	432
12	8190	414	8181	414	8064	404	7818	383
13	8556	366	8546	365	8420	355	8152	335
14	8873	317	8862	316	8726	306	8438	286
15	9141	268	9129	267	8984	258	8675	237
16	9360	219	9348	219	9192	209	8864	188
17	9531	171	9518	170	9353	160	9003	140
18	9653	122	9639	121	9464	111	9094	91
19	9726	73	9711	72	9527	63	9136	42
20	9750	24	9735	24	9541	14	9130	-7
21	9726	-24	9710	-25	9506	-35	9074	-55
22	9653	-73	9636	-74	9422	-84	8970	-104
23	9531	-122	9513	-123	9290	-132	8817	-153
24	9360	-171	9342	-171	9109	-181	8616	-202
25	9141	-219	9122	-220	8879	-230	8365	-250
26	8873	-268	8853	-269	8600	-279	8066	-299
27	8556	-317	8535	-318	8273	-327	7718	-348
28	8190	-366	8169	-366	7897	-376	7322	-397
29	7776	-414	7754	-415	7472	-425	6876	-445
30	7313	-463	7290	-464	6998	-474	6382	-494
31	6801	-512	6777	-513	6476	-522	5839	-543
32	6240	-561	6216	-561	5905	-571	5247	-592
33	5631	-609	5606	-610	5285	-620	4607	-640
34	4973	-658	4947	-659	4617	-669	3918	-689
35	4266	-707	4239	-708	3899	-717	3180	-738
36	3510	-756	3483	-756	3133	-766	2393	-787
37	2706	-804	2678	-805	2318	-815	1558	-835
38	1853	-853	1824	-854	1455	-864	674	-884
39	951	-902	921	-903	542	-912	-259	-933
40	0	-951	-30	-951	-419	-961	-1241	-982
41	-999	-999	-1030	-1000	-1429	-1010	-2271	-1030
42	-2048	-1048	-2079	-1049	-2487	-1059	-3350	-1079
43	-3144	-1097	-3177	-1098	-3595	-1107	-4478	-1128
44	-4290	-1146	-4323	-1146	-4751	-1156	-5655	-1177
45	-5484	-1194	-5518	-1195	-5956	-1205	-6880	-1225

ID: 8

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=4.21			MPG=4.59			MPG=5.59			MPG=6.59	
	TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT
1	926	948		925	925		916	916		895	895
2	1805	879		1803	878		1784	868		1743	848
3	2636	831		2634	830		2605	821		2543	800
4	3420	784		3417	783		3378	773		3296	753
5	4156	736		4152	735		4104	726		4001	705
6	4845	689		4840	688		4782	678		4659	658
7	5486	641		5481	640		5413	631		5269	610
8	6080	594		6074	593		5996	583		5831	563
9	6626	546		6619	545		6532	536		6347	515
10	7125	499		7117	498		7021	488		6814	468
11	7576	451		7568	450		7461	441		7235	420
12	7980	404		7970	403		7855	393		7607	373
13	8336	356		8326	355		8200	346		7932	325
14	8645	309		8634	308		8499	298		8210	278
15	8906	261		8894	260		8750	251		8440	230
16	9120	214		9107	213		8953	203		8623	183
17	9286	166		9273	165		9109	156		8758	135
18	9405	119		9391	118		9217	108		8846	88
19	9476	71		9461	70		9278	61		8886	40
20	9500	24		9484	23		9291	13		8879	-7
21	9476	-24		9460	-25		9257	-34		8824	-55
22	9405	-71		9388	-72		9175	-82		8722	-102
23	9286	-119		9268	-120		9046	-129		8572	-150
24	9120	-166		9101	-167		8869	-177		8374	-197
25	8906	-214		8886	-215		8645	-224		8130	-245
26	8645	-261		8624	-262		8373	-272		7837	-292
27	8336	-309		8315	-310		8054	-319		7497	-340
28	7980	-356		7958	-357		7688	-367		7110	-387
29	7576	-404		7553	-405		7273	-414		6675	-435
30	7125	-451		7101	-452		6812	-462		6193	-482
31	6626	-499		6602	-500		6302	-509		5663	-530
32	6080	-546		6055	-547		5746	-557		5086	-577
33	5486	-594		5460	-595		5142	-604		4461	-625
34	4845	-641		4818	-642		4490	-652		3789	-672
35	4156	-689		4129	-690		3791	-699		3069	-720
36	3420	-736		3391	-737		3044	-747		2302	-767
37	2636	-784		2607	-785		2250	-794		1487	-815
38	1805	-831		1775	-832		1408	-842		625	-862
39	926	-879		895	-880		519	-889		-285	-910
40	0	-926		-32	-927		-418	-937		-1243	-957
41	-974	-974		-1006	-975		-1402	-984		-2247	-1005
42	-1995	-1021		-2028	-1022		-2434	-1032		-3300	-1052
43	-3064	-1069		-3098	-1070		-3513	-1079		-4400	-1100
44	-4180	-1116		-4215	-1117		-4640	-1127		-5547	-1147
45	-5344	-1164		-5379	-1165		-5814	-1174		-6742	-1195

ID: 10

Total Value and Unit (marginal) Value of Different Vehicles

Units	MPG=20			MPG=21.05			MPG=22.05			MPG=23.05	
	TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT		TOTAL	UNIT
1	195	195		191	191		179	179		160	160
2	380	185		372	181		349	169		311	150
3	555	175		544	171		508	159		451	140
4	720	165		705	161		658	149		582	130
5	875	155		856	151		797	139		702	120
6	1020	145		997	141		927	129		813	110
7	1155	135		1129	131		1046	119		913	100
8	1280	125		1250	121		1156	109		1003	90
9	1395	115		1361	111		1255	99		1084	80
10	1500	105		1462	101		1344	89		1154	70
11	1595	95		1554	91		1424	79		1215	60
12	1680	85		1635	81		1493	69		1265	50
13	1755	75		1706	71		1553	59		1306	40
14	1820	65		1767	61		1602	49		1336	30
15	1875	55		1819	51		1642	39		1357	20
16	1920	45		1860	41		1671	29		1367	10
17	1955	35		1891	31		1691	19		1367	0
18	1980	25		1912	21		1700	9		1358	-10
19	1995	15		1924	11		1699	-1		1338	-20
20	2000	5		1925	1		1689	-11		1309	-30
21	1995	-5		1916	-9		1668	-21		1269	-40
22	1980	-15		1897	-19		1638	-31		1220	-50
23	1955	-25		1868	-29		1597	-41		1160	-60
24	1920	-35		1830	-39		1547	-51		1090	-70
25	1875	-45		1781	-49		1486	-61		1011	-80
26	1820	-55		1722	-59		1416	-71		921	-90
27	1755	-65		1653	-69		1335	-81		822	-100
28	1680	-75		1575	-79		1244	-91		712	-110
29	1595	-85		1486	-89		1144	-101		593	-120
30	1500	-95		1387	-99		1033	-111		463	-130
31	1395	-105		1278	-109		913	-121		323	-140
32	1280	-115		1160	-119		782	-131		174	-150
33	1155	-125		1031	-129		642	-141		14	-160
34	1020	-135		892	-139		491	-151		-155	-170
35	875	-145		743	-149		331	-161		-335	-180
36	720	-155		585	-159		160	-171		-524	-190
37	555	-165		416	-169		-20	-181		-724	-200
38	380	-175		237	-179		-211	-191		-933	-210
39	195	-185		48	-189		-412	-201		-1153	-220
40	0	-195		-150	-199		-622	-211		-1383	-230
41	-205	-205		-359	-209		-843	-221		-1622	-240
42	-420	-215		-578	-219		-1073	-231		-1872	-250
43	-645	-225		-807	-229		-1314	-241		-2131	-260
44	-880	-235		-1046	-239		-1564	-251		-2401	-270
45	-1125	-245		-1294	-249		-1825	-261		-2680	-280

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