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Revealed preferences for diamond goods

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Abstract

When consumers do not only care for the intrinsic consumption component of commodities but also for the value of a commodity, it can be rational to purchase products as they become more expensive. Standard revealed preference conditions are however unable to take diamond effects into account. We develop a theoretical model and the associated revealed preference conditions to analyze commodities with different degrees of diamondness. On the basis of real consumer data from the Russian Longitudinal Monitoring Survey, we test the empirical performance of different models with and without diamond effects. It turns out that allowing for diamond effects improves the predictive success of the models. We also link the newly identified diamondness weights to the visibility of commodities. The results suggest that visible goods are more likely to induce diamond effects.
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1 Introduction

Diamond effects The standard (micro)economic literature assumes that consumers derive utility from the quantities they consume. Quantity is perceived as a primary source of utility. However, it has already been recognized that prices can also impact on the utility of consumers. Ng (1987 and 1993) argues that, sometimes, something is purchased for its value rather than for its intrinsic consumption effect. Jewellery is probably the most intuitive example. A diamond is not always purchased for its size. Its value may be more important, as a means to please a beloved one. Similarly, an art collection is valued for its value rather than the number of pieces in this collection (Mandel, 2009). More generally, there are various (visible) goods which can have some degree of diamondness. Whenever people treat their friends to a dinner, go shopping in expensive clothing stores or acquire some collection of wines or cigars, it is not unthinkable that these people care for the value of their purchase.

Analyzing the rationality of consumers in the presence of diamond goods, and studying the nature of different consumer goods, is of major importance. In fact, Ng (1987) presents a parametric framework to test the (welfare) effects of the taxation of diamond goods. Taxing these goods increases government revenue without imposing an overly large burden on consumers, for their utility increases with the price of the diamond goods.

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For this reason, it is important to identify which commodities are standard goods and which are diamond goods. Up to now, little empirical research has been conducted to identify the diamondness of consumption goods while using the criterion of 'rational decision making'. However, Mandel (2009) built on the model of Ng (1987) to analyze situations where the price of art work is included in the utility function of consumers.

Based on data from the Russian Longitudinal Monitoring Survey, we illustrate that allowing for diamond effects has a considerable impact on the empirical performance of the revealed preference characterizations. Moreover, we introduce a measure for the diamondness of various commodities, and test the empirical performance for different values of this measure. We also link the constructed diamondness weights to the visibility of the commodities (based on the visibility ranking in Heffetz, 2011).

Revealed preference Revealed preference models, in the tradition of Samuelson (1938), Afriat (1967), Diewert (1973) and Varian (1982), consist of a number of conditions that need to hold in order for a consumer to be rational. The conditions are derived from a finite set of observables: price and quantity information at different points in time. Under the assumption of preference homogeneity over time, revealed preference theory allows for testing the transitivity of preference relations, without imposing a functional form on the utility functions. Another attractive feature of this methodology is that consumption decisions of different agents can be analyzed independently, thereby fully recognizing that different agents can have different tastes.

In this paper, we argue that letting preferences depend on both quantities and prices does not automatically preclude the decent definition of a revealed preference test. However, we need to modify the test. Standard revealed preference conditions are unable to take diamond effects into account. Individuals are typically assumed to care for quantity (or at least for intrinsic characteristics of the good[1]) but not for the total value of a purchase. Failure to model diamond effects can lead to incorrect conclusions on the rationality of consumers. Consumers' choices which seem irrational according to the standard test may be rationalizable if diamond effects are taken into account, and vice versa. Until now, revealed preference theory for diamond goods is non-existent.

Unfortunately, the theory of revealed preferences and the conjecture that preferences depend on value or prices are difficult to reconcile (see e.g. recent contributions by Bilancini, 2011 and Frank and Nagler, 2012). Revealed preference theory requires a finite data set of consumption choices under different price regimes while maintaining a constant preference ordering. If the preference ordering itself is influenced by prices, revealed preference theory becomes useless because we can not make comparisons of different consumption bundles over time. In the specific case of diamond effects, prices only enter the utility function through total expenditures on some commodity. Hence a homogeneous preference ordering can be defined over the different values of the goods. Yet, if the prices in the utility function (the 'normal' prices) co-move with the prices in the budget constraint (the 'market' prices), the theory of revealed preference loses all of its testable implications, even in our framework.

However, with the distinction between normal and market prices, Pollak (1977) provides a basis for combining the price-dependent preferences on the one hand and the revealed preference logic on the other hand. Specifically, if the normal and market prices do not exactly coincide (or co-move) for all observed commodities, revealed preference theory maintains its testable implications. Of course, the more both prices coincide, the less testable become our models. To test the empirical performance of the different specifications, we use measures which are standard in the revealed preference literature.

Related literature We have argued that the preferences adopted in our framework are a specific case of price-dependent preferences. Prices enter the utility function of consumers, but only through their effect on the value of a purchase. Price-dependent preferences are more general, however, and can be used in vari-

[1]Blow, Browning and Crawford (2005) provide a revealed preference analysis of characteristics models.

ous circumstances[2]. First of all, several studies (dating back to Scitovsky, 1945) discuss *quality effects*. When consumers are satisfied in terms of consumed quantities, they can improve utility by buying the more sophisticated items. Prices then help to identify the products of high quality[3]. Second, Veblen (1899) pointed out that consumption is also driven by *status effects*. Owning highly priced consumption goods signals consumers' ability to purchase expensive goods, and hence, the wealth of the consumer. Conspicuous consumption indicates that consumers buy the more expensive commodities to 'show off'[4].

In this respect, it is also interesting to report two empirical studies which do not exactly cover diamond effects but which implicitly or explicitly focus on consumption choices when preferences are allowed to depend on the value or price of commodities.

Scott and Yelowitz (2010) focus on one commodity in particular: diamonds. The authors compare the marginal willingness to pay for diamonds with the price which is justified on the basis of the mere quality of the diamonds. It is found that consumers are willing to pay 18% more for a diamond of one-half carat than for a diamond which is only slightly less than one-half carat, for instance. The authors explain this anomaly by arguing that offering a diamond of one-half carat to someone creates a totally different perception than offering a diamond of 0.499 carat. People care about the value of the diamond.

Because we investigate different commodity groups rather than focusing on one commodity in particular, and because we build our analysis on a structural model of consumer behaviour, our research is closer related to a study by Basmann, Molina and Slottje (1988). Basmann, Molina, and Slottje (1988) assume that consumers maximize a generalized Fechner-Thurstone type utility function subject to a classical budget constraint. While maintaining rationality as a test criterion, the authors allow for price-dependent preferences. Their empirical application uses consumer data on 5 commodity groups (food, clothing, housing, durables and medical care) to test Veblen's theory of conspicuous consumption. Although related, our study is different in at least two ways. First, we use information on the consumption of 14 different commodies (including luxuries) to investigate diamond effects (rather than pure status effects). Therefore, prices only enter the utility function because of their effect on the total value of a purchase. Second, and more importantly, our nonparametric approach imposes minimal structure on the utility functions of consumers.

Contribution The contribution of this paper is three-fold.

On the theoretical level, we present an empirically tractable model of individual rationality in the presence of diamond effects. This model is more general than the existing model of utility maximization over quantities and more general than the models of Ng (1987 and 1993), which value one particular diamond good at market prices. We make a distinction between models with pure diamond effects (based on Ng, 1987) and models with mixed diamond effects (based on Ng, 1993). While the former is more powerful (see infra) the latter may be more realistic (utility can be derived both from the intrinsic consumption and from the market

[2]Pollak (1977) provides an insightful overview of the modelling of price-dependent preferences. The author considers two distinct ways in which price-dependent preferences are analyzed: the unconditional approach and the conditional approach. According to the unconditional approach, economic agents express their preferences, not only over quantities, but over price-quantity pairs (see e.g. Kalman, 1968 and Piccione and Rubinstein, 2008). In this case, welfare conclusions are still possible (there exists a homogeneous preference ordering defined over quantities and prices) but the model can not be tested on the basis of data from standard consumption surveys, where people choose quantities and not price-quantity pairs. Because data on choices over price-quantity pairs (at any moment in time) are generally unavailable, the conditional approach seems most popular in empirical work. Following this approach, the preference orderings (defined over quantities) are conditional on prices. A popular functional specification for the utility function - which accounts for preference shifting parameters such as prices - is the generalized Fechner-Thurstone utility function. However, this utility function does not allow for welfare comparisons between periods where the preference shifting parameters (i.e. the prices) take different values.

[3]Empirical evidence for the relationship between prices and perceived quality is somewhat unclear, though. Zeithaml (1988) argues that a general positive relationship between price on the one hand and quality on the other hand is not confirmed in many empirical studies.

[4]However, this only makes sense when prices of status goods are visible to other consumers. Bagwell and Bernheim (1996), for instance, argue that modelling status through the commodities' prices alone is rather restrictive.

value of a commodity). More generally, this paper can be seen as a first attempt to build a bridge between the literature on diamond effects on the one hand and the literature on the revealed preference methodology on the other hand. Instead of just abandoning one of these separate literatures, we develop a way in between, by using Pollak's distinction between market prices (prices in the budget constraint) and normal prices (prices in the utility functions). A new (set of) parameter(s), the so called diamondness weights, captures the responsiveness of normal prices to current market prices.

On the methodological level, we present the revealed preference characterizations that are associated with different specifications of our models with (pure and mixed) diamond effects. Each specification corresponds to a particular set of values which is imposed on the diamondness weights. By varying the values of these diamondness weights, we can move from the classical model of utility maximization to a model where market prices and normal prices co-move exactly. Interestingly, we can test these different specifications (and hence the different assumptions on the diamondness weights) by using performance measures which are standard in revealed preference analysis. Moreover, it turns out that the different specifications of the models with diamond effects are generally non-nested. As such, it is not necessarily the case that a data set is consistent with a model with strictly positive diamondness for some commodities when it is consistent with the predictions of the classical model, or vice versa. This will be illustrated using two examples in Section 3.

On the empirical level, we show that the revealed preference characterizations provide us with an easy test for rationality in the presence of diamond effects. In fact, by repeating this test for different values of the diamondness weight, and by assessing the standard empirical performance measures associated with these specifications, we can effectively identify the most realistic diamondness weight per commodity. In this way, our study contributes to the empirical identification of diamond goods. Furthermore, we investigate the goodness-of-fit of our models, i.e. we compute the largest number of subsequent time periods during which the consumers have chosen in line with some specification. The length of this period will be influenced by the postulated diamondness weights. Finally, we investigate whether the more visible commodities (based on the visibility ranking in Heffetz, 2011) also obtain higher diamondness weights in our analysis.

Outline In Section 2, we first provide a discussion of the framework in which diamond effects can be analyzed. We also discuss the difference between market prices and normal prices, and the relationship between both concepts. Next, we introduce the formal models with pure and mixed diamond effects, inspired by Ng (1987 and 1993). In Section 3, we present the revealed preference characterizations that correspond to the aforementioned models. These characterizations contain conditions which can be tested using linear programming techniques. We discuss our data set from the Russian Longitudinal Monitoring Survey in Section 4. Section 5 presents measures for the empirical performance of the revealed preference characterizations, including pass rates, discriminatory power and predictive success. Our empirical results are presented in Section 6. Section 7 concludes.

2 Diamond effects

In this section, we formally present the distinction between market prices (the prices which enter the budget constraint) and normal prices (the prices which enter the utility function). Before we introduce the models, we briefly discuss the relationship between normal prices and market prices. In Subsection 2.2, the model with **pure** diamond effects is presented. Following this model, utility can not be derived both from intrinsic consumption and from the exact market value of some commodity. In the model with **mixed** diamond effects, presented in Subsection 2.3, the intrinsic consumption component and the market value can enter the utility function simultaneously.

2.1 Normal price function

Because our focus is on diamond effects, we let the value of commodities enter the utility function of consumers[5]. The price of some commodity can only affect preferences via the expenditures on this commodity. Therefore, it remains possible to have a homogeneous preference ordering over time U (provided that the social environment is rather stable and so on), hence welfare comparisons and the revealed preference approach are still valid. This contrasts with the conditional approach to the (more general) price-dependent preferences, where preferences are conditional on prices and where prices do not necessarily enter the utility function via the expenditures. Revealed preference theory is attractive because it imposes minimal structure on the utility functions, such that we are able to analyze the rationality of each individual separately (and account for unobserved heterogeneity).

Ng (1987) introduces a model where one good is assumed to be a (pure) diamond good, i.e. the market value of this commodity enters the utility function of consumers. In a later paper, Ng (1993) also allows for mixed diamond goods, where both the market value and the intrinsic consumption component of one (mixed) diamond good enter the utility function. Unfortunately, in the framework of Ng (1987 and 1993), there is only one pure or mixed diamond good. The other goods are standard goods. In this paper, we present a framework where, in principle, *all* goods are allowed to have diamondness, and where diamondness is expressed on a continuum between 0 and 1 (rather than a framework where goods can only be divided into 2 groups: diamond goods and standard goods). In order to allow for different degrees of diamondness in this revealed preference framework, we make use of Pollak's distinction between normal prices δ_t and market prices $\mathbf{P}_t$. Specifically, consumers are now assumed to optimize

$$\max_{\mathbf{Q}} U(\delta_t \mathbf{Q})$$

by choosing optimal levels of $\mathbf{Q}$. The normal prices δ_t can, but in general must not, be equal to the current market prices $\mathbf{P}_t$. In fact, the way in which normal prices depend on market prices is of major importance. As argued by Pollak (1977) and acknowledged by Frank and Nagler (2012), revealed preference theory is only useful whenever the normal prices and market prices vary independently of one another. Otherwise stated, if the normal and market prices coincide exactly, the revealed preference models lose testability. In this specific case, where prices enter the utility function as a factor of quantities, equality of normal and market prices would suggest that the preference ranking of bundles can be constructed in line with total expenditures: more expensive bundles would always be better. Hence, contradictions and rejections of the revealed preference conditions would not occur, and consumers' choices would always be trivially rationalizable.

In the following, we specify the way in which normal prices depend on market prices, i.e. the normal price function (Pollak, 1977). Pollak (1977) describes an appealing special case of this normal price function, in which normal prices are a weighted average of all market prices. In our framework, a natural choice is to specify the normal price function as a weighted average of the current market price and a past reference price index[6].

$$\forall n \in N : \delta_t^{n\prime} = \theta^n * P_t^n + (1 - \theta^n) * P_{reference}^n$$

This function satisfies the nonnegativity and homogeneity (of degree one) assumptions in Pollak (1977). Furthermore, for positive values of θ^n, the normal prices $\delta_t^{n\prime}$ and the market prices P_t^n converge towards the same configuration. The θ^n parameters will be called diamondness weights for the remainder of this study. Imposing this structure on the normal price function is useful for a number of reasons. First of all,

[5] Other studies where prices enter the utility function as a factor of quantities include Ng (1987 and 1993), Weber (2002), Deng and Ng (2004), Mandel (2009) and Engström (2011).

[6] In Appendix B, we show that our resuls can easily incorporate a more general normal price function. However, this more general function increases the number of coefficients to be estimated, and it makes the interpretation of the coefficients more difficult.

this normal price function makes it possible to distinguish clearly between situations where market prices and normal prices coincide and situations where market prices and normal prices vary independently. Second, the final specification of the normal price function will depend on the choice of certain (diamondness) parameters. Interestingly, by deriving the revealed preference characterizations for different values of the underlying parameters, we are effectively able to test each specification of the normal price function that we consider.

An interesting interpretation is obtained when the normal prices are deflated by $P^n_{reference}$ in all periods. First of all, this transformation has no effect on the revealed preference outcomes (remember that the utility function remains unspecified; it is only assumed to be homogeneous across periods). Multiplying some argument in the utility function by a constant scalar in all waves does not change the revealed preference restrictions. One should just bear in mind that all market prices are now expressed in relation to this reference index. In our study, we choose the market prices in the first wave as the reference prices, $P^n_{reference} = P^n_1$. Second, it provides us with a normalized price index $P'^n_t = \dfrac{P^n_t}{P^n_1}$, which might be more realistic, as consumers may evalute price changes in proportion to an earlier price (in this case P^n_1) of the same good[7].

$$\forall n \in N : \delta^n_t = \theta^n * P'^n_t + (1 - \theta^n) * 1$$

In some sense, the diamondness weights capture the responsiveness of the normal prices to changes in the (normalized) market prices. Indeed, if P'^n_t is raised by 1, the normal price increases by θ^n. If $\theta^n = 1$, this implies that normal prices co-move with (normalized) market prices one-to-one. If $\theta^n = 0$, then the normal prices are independent of the (normalized) market prices. Then the above maximization problem reduces to the classical model with standard goods:

$$\max_{\mathbf{Q}} U(\mathbf{Q})$$

In this case, the observed demands should satisfy the standard properties of negative semi-definiteness and symmetry of the Slutsky matrix. If, on the other hand, $\theta^n > 0$, then the implied substitution matrix need no longer be negative semi-definite or symmetric (note that symmetry and negative semi-definiteness are often rejected in empirical tests of the standard unitary model). When *all* normal prices and (current) market prices co-move exactly ($\theta^n = 1, \forall n \in N$), we have the so called *simultaneous specification*. In this case, our models lose testability (Bilancini, 2011 and Frank and Nagler, 2012).

2.2 Model with pure diamond effects

Suppose that we have a data set $S = \{\mathbf{P}_t, \mathbf{Q}_t \,|\forall t \in T\}$ which consists of T observations. For each observation t, this data set contains information on the observed quantity vector $\mathbf{Q}_t \in \mathbb{R}^{|N|}_+$ and the corresponding price vector $\mathbf{P}_t \in \mathbb{R}^{|N|}_{++}$. The prices denoted by $\mathbf{P}'_t = \dfrac{\mathbf{P}_t}{\mathbf{P}_1}$ are the normalized current market prices.

The variable δ_t is the vector of prices that enter the utility function. As such, utility is not derived from the observed consumption quantities per se, it is derived from the value associated with consuming $\mathbf{Q}_t$ at prices $\mathbf{P}_t$, namely $\delta_t \mathbf{Q}_t$. Finally, δ^n_t is defined as the weighted average of the (normalized) current market price P'^n_t and one. The diamondness weights θ^n can take any value between 0 and 1.

Problem 1 *Optimization problem $\theta-$PDE*

$$\max_{\mathbf{Q}} U(\delta_t \mathbf{Q})$$

[7] Suppose that shoes cost 5 tokens and jackets cost 10 tokens in period 1, and shoes cost 6 tokens and jackets 9 tokens in period 2. The normalized price index associated with shoes will be higher than the same price index associated with jackets, in period 2. Indeed, shoes have become more expensive.

$$s.t.$$

$$\mathbf{P}_t\mathbf{Q} \leq y_t$$

$$\forall n \in N : \delta_t^n = \theta^n * P_t'^n + (1 - \theta^n) * 1$$

Revealed preference theory then proceeds by looking for some utility function U such that the observed consumption pattern solves Problem 1.

Definition 2 *Consider a data set $S = \{\mathbf{P}_t, \mathbf{Q}_t \,|\forall t \in T\}$. We say that S is rationalizable with **pure** $\theta-$diamond effects if there exists a utility function U defined over values $\delta\mathbf{Q}$ such that $\{\mathbf{Q}_t; \forall t \in T\}$ solves optimization problem $\theta-$PDE.*

It is easily seen that rationalizability with pure $\theta-$diamond effects comprises rationalizability by a standard utility function, rationalizability by a utility function following Ng (1987) and rationalizability by a utility function which is non-decreasing in total expenditures. Let us briefly discuss these three (rather extreme) specifications:

- First, if all goods are standard goods ($\theta^n = 0$ for all n) then the prices δ_t^n are constant and equal to 1 across the different observations t. In this case, the quantities $\mathbf{Q}$ in the utility function are all multiplied by 1, which boils down to the classical formulation of the utility function. Differences in marginal utility associated with consumption are therefore uniquely driven by differences in the marginal utility of the intrinsic consumption component, i.e. the quantity denoted by $\mathbf{Q}$. So, when all δ_t^n are set to unity, diamond effects are excluded from the model.

- Second, if there is exactly one diamond good i (such that $\theta^i = 1$ and $\theta^n = 0$ for all $n \neq i$), the optimization problem reduces to the model with *pure* diamond effects by Ng (1987). Indeed, we have that if $\mathbf{Q}_t$ maximizes $U(\delta_t\mathbf{Q})$, it should also maximize $U(P_t'^iQ^i, Q^n)$ and $U'(P_t^iQ^i, Q^n)$. The final step follows from the fact that if $\mathbf{Q}_t$ solves Problem 1 for some utility function $U(.)$, there will also exist a utility function $U'(.)$ such that $\mathbf{Q}_t' = \Gamma\mathbf{Q}_t$ solves Problem 1, where Γ is a vector of scalars which are constant across all t. Otherwise stated, multiplying an argument of the utility function by a constant scalar (across all t) does not affect the revealed preference results. We effectively obtain a characterization which is very similar to the model by Ng (1987).

- Finally, if all goods are diamond goods ($\theta^n = 1$ for all n) then the observed consumption vector $\mathbf{Q}_t$ maximizes $U(\mathbf{P}_t'\mathbf{Q})$ and, equivalently, $U'(\mathbf{P}_t\mathbf{Q})$. Again, the final step follows from the fact that utility functions are not specified, there must only exist one utility function such that $\mathbf{Q}_t$ solves Problem 1. These results are independent of homogeneous transformations (over time t) of some argument in the utility function. Since $\mathbf{Q}_t$ maximizes $U'(\mathbf{P}_t\mathbf{Q})$, subject to a budget constraint, utility is exclusively derived from the money spent on commodities.

2.3 Model with mixed diamond effects

The model, presented in Subsection 2.1, is restrictive in the sense that it is implicitly assumed that there exists a negative relationship between the responsiveness of normal to market prices on the one hand and the utility derived from the intrinsic consumption component of commodities on the other hand. In this subsection, we present a model where utility is (can be) derived from the intrinsic consumption component, irrespective of the responsiveness of normal to market prices, hence irrespective of the diamondness weights θ^n. In this case, consumers can derive utility both from the intrinsic consumption and from the market-price based value of commodities.

We therefore introduce the following optimization problem:

Problem 3 *Optimization problem $\theta-$MDE*

$$\max_{\mathbf{Q}} U(\mathbf{Q}, \delta_t \mathbf{Q})$$

$$s.t.$$

$$\mathbf{P}_t \mathbf{Q} \leq y_t$$

$$\forall n \in N : \delta_t^n = \theta^n * P_t'^n + (1 - \theta^n) * 1$$

Observe, first of all, that whatever the values of θ^n are, the above optimization problem takes into account that utility could be derived from the intrinsic consumption component $\mathbf{Q}$. The constraints are identical to the restrictions in Problem 1.

Next, we define rationalizability with *mixed* diamond effects in a revealed preference setting.

Definition 4 *Consider a data set $S = \{\mathbf{P}_t, \mathbf{Q}_t \,|\forall t \in T\}$. We say that S is rationalizable with **mixed** $\theta-$diamond effects if there exists a utility function U defined over the intrinsic consumption component $\mathbf{Q}$ and the valuation $\delta\mathbf{Q}$ such that $\{\mathbf{Q}_t; \forall t \in T\}$ solves optimization problem $\theta-$MDE.*

- Consider first the scenario where all goods are standard goods ($\theta^n = 0$ for all n). Then the prices δ_t^n are constant and equal to one across the different observations t. Therefore, utility is only derived from the intrinsic consumption component $\mathbf{Q}$. Obviously, this all implies that, just as in Subsection 2.1, the optimization problem coincides with the classical model of utility maximization.

- Next consider a scenario with exactly one (mixed) diamond good i ($\theta^i = 1$ and $\theta^n = 0$ for all $n \neq i$). The corresponding optimization problem reduces to the model with *mixed* diamond effects by Ng (1993). In this case, both the intrinsic consumption component and the market-price valuation of commodity i are included in the utility function. Note that if $\mathbf{Q}_t$ maximizes $U(\mathbf{Q}, \delta_t\mathbf{Q})$, it will also maximize $U(Q^i, Q^n, P_t'^i Q^i, Q^n)$ and, because homogeneous transformations of arguments in the utility functions do not affect the revealed preference results, $U'(Q^i, Q^n, P_t^i Q^i)$. This specification coincides with the model by Ng (1993).

- Finally, if all goods are (mixed) diamond goods, the observed consumption vector $\mathbf{Q}_t$ maximizes utility $U(\mathbf{Q}, \mathbf{P}_t'\mathbf{Q})$ and hence $U'(\mathbf{Q}, \mathbf{P}_t\mathbf{Q})$. Both the intrinsic consumption components of commodities and their corresponding market values enter the utility function.

3 RP characterizations with diamond effects

In the previous section, we have formulated two models which are more general than the standard utility maximization model on the one hand, and the models of Ng (1987 and 1993) on the other hand. We have also defined rationalizability in the presence of pure and mixed diamond effects, without imposing too much structure on the utility functions. Our approach is nonparamatric. In this section, we propose various conditions by which the different rationalizability concepts can be tested. It turns out that these conditions are linear in all unknowns. They can therefore be tested by means of appropriate linear programming problems.

3.1 RP characterization with pure diamond effects

First, we develop a test for rationalizability with pure $\theta-$diamond effects. Hence, we must verify whether there exists a well-behaved (monotone and concave) and differentiable utility function such that $\{\mathbf{Q}_t; \forall t \in T\}$

solves Problem $\theta-$PDE. Starting from the concavity of the utility function, we have that for all t and v, the following conditions must hold:

$$U(\delta_t \mathbf{Q}_t) - U(\delta_v \mathbf{Q}_v) \leq \sum^n \frac{\partial U(\delta_v \mathbf{Q}_v)}{\partial \delta_v^n Q_v^n}(\delta_t^n Q_t^n - \delta_v^n Q_v^n)$$

Next, the first-order conditions associated with Problem $\theta-$PDE imply that

$$\frac{\partial U(\delta_t \mathbf{Q})}{\partial \delta_t^n Q^n}\delta_t^n = \lambda_t P_t^n$$

where λ_t is the strictly positive Lagrange multiplier which is associated with the budget constraint. By substituting both conditions, and by setting $u_t = U(\delta_t \mathbf{Q}_t)$ and $u_v = U(\delta_v \mathbf{Q}_v)$, we finally obtain the following proposition.

Proposition 5 *Consider a data set $S = \{\mathbf{P}_t, \mathbf{Q}_t \,|\forall t \in T\}$ and suppose that $\mathbf{P}'_t = \dfrac{\mathbf{P}_t}{\mathbf{P}_1}$. The following conditions are equivalent:*

1. *The data set is rationalizable with **pure** $\theta-$diamond effects.*
2. *For all decision situations $t \in T$ and for all commodities $n \in N$, there exist normal prices $\delta_t = (\delta_t^1, ..., \delta_t^N) \in \mathbb{R}_{++}^{|N|}$, numbers u_t and (Lagrange) multipliers $\lambda_t \in \mathbb{R}_{++}$ such that*

$$u_t - u_v \leq \lambda_v \sum^n P_v^n / \delta_v^n * (\delta_t^n Q_t^n - \delta_v^n Q_v^n)$$

$$\forall n \in N : \delta_t^n = \theta^n * P_t'^n + (1 - \theta^n) * 1$$

The Proof is in Appendix A. It is easy to verify that the above inequalities reduce to the well-known Afriat inequalities when all $\theta^n = 0$. By contrast, when all $\theta^n = 1$, a preference ordering which is monotonically increasing in the total budget $y_t = \mathbf{P}_t \mathbf{Q}_t$ of the consumer can always rationalize data set S. Note that the inequalities are not linear, because both λ_v and δ_v^n are initially unknown. However, by fixing the diamondness weights to some value between 0 and 1, we determine the values δ_v^n. Then the conditions are linear in the variables u_t, u_v and λ_v. Of course, the different parameterizations of θ^n will be tested using standard predictive success measures from the revealed preference literature.

3.2 RP characterization with mixed diamond effects

Second, we develop a test for rationalizability with mixed $\theta-$diamond effects. We investigate whether it is possible to construct a well-behaved utility function U, with both values $\delta\mathbf{Q}$ and quantities $\mathbf{Q}$ as arguments, such that the observed consumption pattern $\{\mathbf{Q}_t; \forall t \in T\}$ solves Problem $\theta-$MDE. Again, we start from the concavity of the utility function. For all t and v, we must have that

$$U(\mathbf{Q}_t, \delta_t \mathbf{Q}_t) - U(\mathbf{Q}_v, \delta_v \mathbf{Q}_v) \leq \sum^n \frac{\partial U(\mathbf{Q}_v, \delta_v \mathbf{Q}_v)}{\partial Q_v^n}(Q_t^n - Q_v^n) + \frac{\partial U(\mathbf{Q}_v, \delta_v \mathbf{Q}_v)}{\partial \delta_v^n Q_v^n}(\delta_t^n Q_t^n - \delta_v^n Q_v^n)$$

Moreover, the first-order conditions, with respect to $\mathbf{Q}$, associated with Problem $\theta-$MDE imply that

$$\frac{\partial U(\delta_t \mathbf{Q})}{\partial Q^n} + \frac{\partial U(\delta_t \mathbf{Q})}{\partial \delta_t^n Q^n}\delta_t^n = \lambda_t P_t^n$$

The first term is the derivative of the utility function with respect to quantity (or intrinsic consumption) whereas the second term is the derivative of the utility function with respect to value (normal prices multiplied by quantities). Of course, these first-order conditions must hold for all $n \in N$. We introduce shadow prices $\mathfrak{p}_t^n$ and $\mathfrak{P}_t^n$ such that $\mathfrak{p}_t^n = \partial U_t / \partial Q_t^n$ and $\mathfrak{P}_t^n = \partial U_t / \partial (\delta_t^n Q_t^n)$. We also set $u_t = U(\mathbf{Q}_t, \delta_t \mathbf{Q}_t)$ and $u_v = U(\mathbf{Q}_v, \delta_v \mathbf{Q}_v)$. Then we can formulate our final proposition.

Proposition 6 *Consider a data set $S = \{\mathbf{P}_t, \mathbf{Q}_t \mid \forall t \in T\}$ and suppose that $\mathbf{P}'_t = \dfrac{\mathbf{P}_t}{\mathbf{P}_1}$. The following conditions are equivalent:*

1. *The data set is rationalizable with **mixed** $\theta-$diamond effects.*
2. *For all decision situations $t \in T$ and for all commodities $n \in N$, there exist normal prices $\delta_t = (\delta_t^1, ..., \delta_t^N) \in \mathbb{R}_{++}^{|N|}$, numbers u_t, (Lagrange) multipliers $\lambda_t \in \mathbb{R}_{++}$ and shadow prices $\mathfrak{p}_t \in \mathbb{R}_{++}^{|N|}$ and $\mathfrak{P}_t \in \mathbb{R}_{++}^{|N|}$ such that:*

$$u_t - u_v \leq \sum^{n} \mathfrak{p}_v^n * (Q_t^n - Q_v^n) + \sum^{n} \mathfrak{P}_v^n * (\delta_t^n Q_t^n - \delta_v^n Q_v^n)$$

$$\forall n \in N : \lambda_v P_v^n = \mathfrak{p}_v^n + \mathfrak{P}_v^n * \delta_v^n$$

$$\forall n \in N : \delta_t^n = \theta^n * P_t'^n + (1 - \theta^n) * 1$$

The Proof is in Appendix B. It is easy to show that, when all $\theta^n = 0$, the inequalities coincide with the standard Afriat conditions. By contrast, when all $\theta^n = 1$, a preference ordering which is monotonically increasing in the total budget $y_t = \mathbf{P}_t \mathbf{Q}_t$ of the consumer can always rationalize the data. The conditions in Proposition 8 are linear in the variables $u_t, u_v, \lambda_t, \mathfrak{p}_t$ and $\mathfrak{P}_t$ for fixed values of θ^n. Again, the 'optimal' values for θ^n (in terms of predictive success) can be determined by performing a grid search on the intervals $[0, 1]$.

Note that the above characterization also allows to analyze the consumption of commodities beyond their point of saturation. The classical model predicts that additional units should not be purchased when a commodity has become a bad. However, in the presence of diamond effects, it may be rational to purchase additional units even though the marginal utility associated with the intrinsic consumption component of some commodity has become negative. A very nice example is discussed in Ng (1993). Suppose I take my colleagues to a pub. I want to show my appreciation for their fellowship by buying them some drinks. In this case, the total value associated with offering an additional round is more important than my utility derived from the intrinsic consumption component of this purchase. It is not unthinkable, after a point of saturation, that I am not thirsty anymore and that my marginal utility from consuming an additional unit has become negative: $\mathfrak{p}_v < 0$. Still, I am willing to treat my colleagues to an additional round of drinks, because I prefer to increase the total value of my offer: $\mathfrak{P}_v > 0$. If the latter effect (utility increases with total value) outweighs the former (utility decreases with the consumed quantity after the saturation point), an equilibrium solution might effectively be achieved even if the marginal utility of the intrinsic consumption component has become negative. Summarizing, testing whether a commodity n has become a bad is easy. One can simply add the requirement

$$\mathfrak{p}_v < 0$$

to the revealed preference characterization in Proposition 8.

3.3 Independence

With diamondness weights θ^n that can take any value between 0 and 1, it is clear that the models with pure and mixed diamond effects are more general than the classical model. Indeed, the models with pure and mixed diamond effects encompass the classical model when θ^n is set to 0 for all goods.

In the empirical application, we compare different specifications of the models with pure and mixed diamond effects. Each specification corresponds to the general model (with pure or mixed diamond effects) where the diamondness weights are fixed to a particular set of values. It turns out that these specifications are independent. Otherwise stated, the specification where all θ^n are set to 0 (which corresponds to the classical model) and other specifications with strictly positive diamondness weights for some commodities are generally non-nested[8].

It is possible that a data set violates the predictions of the classical model while the data set is consistent with the predictions of an alternative model with strictly positive θ^n for some goods. Likewise, it is possible that a data set is consistent with the classical model while the data set violates the predictions of the alternative model for some strictly positive values of θ^n. To demonstrate this non-nestedness, we use two examples. The first example shows a data set which is not rationalizable when all goods are standard goods but which is rationalizable when one good is a (pure) diamond good.

Example 7 *Consider a data set with $T = 2, N = 2$, market price vector $\mathbf{P} = \begin{pmatrix} 3 & 1 \\ 1 & 3 \end{pmatrix}$ and quantity vector $\mathbf{Q} = \begin{pmatrix} 3 & 1 \\ 1 & 3 \end{pmatrix}$.*

Let us show that this data set violates the standard Afriat inequalities.

$$\begin{aligned} &[\mathbf{P}_1\mathbf{Q}_1 = 10] > [\mathbf{P}_1\mathbf{Q}_2 = 6] \Rightarrow u_1 > u_2 \\ &[\mathbf{P}_2\mathbf{Q}_2 = 10] > [\mathbf{P}_2\mathbf{Q}_1 = 6] \Rightarrow u_2 > u_1, \\ &\textit{a contradiction} \end{aligned}$$

The following shows that the data set is consistent with a model where good 1 is a (pure) diamond good ($\theta^1 = 1$).

$$\begin{aligned} &[P_1^1Q_1^1 + P_1^2Q_1^2 = 10] > [P_2^1Q_2^1 + P_1^2Q_2^2 = 4] \Rightarrow u_1 > u_2 \\ &[P_2^1Q_2^1 + P_2^2Q_2^2 = 10] < [P_1^1Q_1^1 + P_2^2Q_1^2 = 12] \not\Rightarrow u_2 > u_1, \\ &\textit{we find no contradiction} \end{aligned}$$

The second example shows a data set which is rationalizable when all goods are standard goods but which is not rationalizable when one good is a (pure) diamond good.

Example 8 *Consider a data set with $T = 2, N = 3$, market price vector $\mathbf{P} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 3 & 2 \end{pmatrix}$ and quantity vector $\mathbf{Q} = \begin{pmatrix} 1 & 9 & 10 \\ 9 & 3 & 0 \end{pmatrix}$.*

Let us show that this data set is consistent with the standard Afriat inequalities.

$$\begin{aligned} &[\mathbf{P}_1\mathbf{Q}_1 = 49] > [\mathbf{P}_1\mathbf{Q}_2 = 15] \Rightarrow u_1 > u_2 \\ &[\mathbf{P}_2\mathbf{Q}_2 = 45] < [\mathbf{P}_2\mathbf{Q}_1 = 51] \not\Rightarrow u_2 > u_1, \\ &\textit{we find no contradiction} \end{aligned}$$

[8] There is one exception: the specification where all diamondness weights equal one can never reject rationality. Hence, this specification is always weaker than all other specifications.

The following shows that the data set can not be rationalized when good 2 is a (pure) diamond good ($\theta^2 = 1$).

$$[P_1^1 Q_1^1 + P_1^2 Q_1^2 + P_1^3 Q_1^3 = 49] > [P_1^1 Q_2^1 + P_2^2 Q_2^2 + P_1^3 Q_2^3 = 18] \Rightarrow u_1 > u_2$$
$$[P_2^1 Q_2^1 + P_2^2 Q_2^2 + P_2^3 Q_2^3 = 45] > [P_2^1 Q_1^1 + P_1^2 Q_1^2 + P_2^3 Q_1^3 = 33] \Rightarrow u_2 > u_1,$$

a contradiction

4 Data

To test our revealed preference characterizations with and without pure and mixed diamond effects, we make use of consumer data from the Russian Longitudinal Monitoring Survey, from 1994 to 2006, with the exception of 1997 and 1999. These 11 waves correspond to the second collection phase of the RLMS data (Phase II). To do revealed preference analysis based on these data, we assume that the social environment of the respondents is relatively stable. Remember that revealed preference analysis requires homogeneous preferences over time. Importantly, we restrict attention to data sets of singles who do not receive any unemployment benefits. Furthermore, we only keep singles which report expenditures for the 11 waves. In this way, we end up with a sample of 81 singles.

For each person, we have information on the expenditures and the consumed quantities associated with 14 commodity groups[9]. Note that all commodities are rather nondurable. We exclude 'big' decisions on housing and cars from the data sets. The reason is straightforward: we want to make a clear distinction between decisions driven by diamond effects on the one hand and intertemporal portfolio decisions on the other hand. Since the focus of this paper is on the former, we only consider nondurable commodities.

From the (nominal) expenditures and the quantities, it is possible to derive unit prices. Note that these prices are often a weighted geometric mean of the prices associated with various detailed subgroups of goods. For instance, the price of meat is a weighted geometric mean of the prices of beef, pork, organs, poultry, etc. Furthermore, we use average prices per region and per wave, i.e. it is assumed that singles who are consuming in the same region and wave face the same prices. Finally, the prices are transformed in order to eliminate the effects of (hyper)inflation. As such, we avoid that price changes due to inflation impact on the consumption decisions of consumers. The (implicit) assumption that there is no money illusion seems standard in many studies that involve price-dependent preferences. The transformation of prices does not affect the relative prices between commodities, which drive revealed preference analysis.

In order to limit the number of diamondness weights to be estimated in the empirical application, we can further aggregate the 14 commodities into 6 important categories: food at home, vices (alcohol and tobacco), food outside home, clothing, fuel and luxuries. These categories can further be divided into two subgroups. Food at home and fuel can be distinguished from vices, food outside home, clothing and luxuries on the basis of a visibility ranking, created by Heffetz (2011). To create this ranking, Heffetz (2011) used information from 480 interviews on the visibility of various commodities. The main question in Heffetz' survey was whether respondents would notice if another household spent more than average on some commodity (e.g. jewellery and watches). Respondents were also asked how much time it would take to notice this more-than-average spending pattern. In this way, the commodities (not brands) which are most visible to society were expected to obtain a high rank.

Tobacco (ranked 1th), clothing (ranked 3th), jewellery (ranked 5th), food outside home (ranked 7th) and alcohol (ranked 8th) are all part of the top-10 most visible commodities according to Heffetz' (2011) ranking. Therefore, we assign these commodities to the 'visible' subgroup. Food at home (ranked 14th) and gasoline (ranked 21th) were ranked considerably lower. These commodities are collected in the 'invisible' subgroup. We have already argued that diamond effects are conceptually different than status effects. Status effects,

[9]The commodity groups are similar to the ones considered by Cherchye, De Rock and Vermeulen (2009): bread, potatoes, vegetables, fruit, meat, dairy products, alcohol, tobacco, food outside home, clothes, fuel (car), fuel (wood), fuel (gas) and luxury products.

on the one hand, imply a very specific interpretation of the effect of prices on preferences. Consumers are supposed to buy expensive items to 'show off'. The definition of diamond effects, on the other hand, is more general: something is valued for its value rather than for its intrinsic consumption components. One can not exclude the possibility that consumers want to 'show off' and therefore value the value of commodities. Therefore, we would expect that pure and mixed diamond effects associated with commodities in the visible subgroup are (somewhat) more outspoken. Our characterizations would thus be empirically supported if higher diamondness weights for these commodities improved the empirical success of our models. Note however that there are alternative motivations for modelling diamond effects, which do not rely on conspicuous consumption[10]. Similarly, there may be other interesting visibility measures which capture various dimensions of the exposure of commodities to society. The following results should thus be interpreted with care. The main purpose of this empirical application is to show how the revealed preference measures are affected by the assumptions on the diamondness of different commodities. Revealed preference measures are presented in the next section.

5 Empirical performance

In order to assess the empirical success of the different characterizations, we refer to some measures which are commonly used in revealed preference analysis. Specifically, we focus on pass rates, power and predictive success of the various models.

Pass rates An attractive feature of the revealed preference framework is that each consumer can be analyzed separately. Otherwise stated, we can run an independent test for the rationality of each consumer, in the presence or absence of pure or mixed diamond effects. In this way, we have 81 responses which can either be equal to 1 (then the individual's behaviour can be rationalized by some well-behaved utility function) or 0 (then the individual's behaviour can not be rationalized by a utility function) for some specification of the diamondness weight. By computing the average response, we obtain one possible measure for the empirical performance of our models: the pass rate. Hence, if the pass rate equals 1, then each of the 81 individuals has chosen consistently with the specified model. A pass rate of 0 would indicate that no agent is rational according to the model.

Power Given that it is our purpose to compare characterizations with different diamondness weights, we also need to apply a measure for the meaningfulness of our models. It is easy to show why such measure is necessary. A characterization where all diamondness weights are set to 1 would impose no meaningful restrictions on our data sets. In such case, the normal prices (Pollak, 1977) coincide with the market prices for all commodities. Bilancini (2011) and Frank and Nagler (2012) have rightfully argued that revealed preference theory is useless when preferences as well as the budget sets are driven by the market prices. Any pattern of choices can trivially satisfy the revealed preference conditions. Moreover, even if normal prices and market prices do not co-move exactly, the power of our models can be influenced by the choice of the diamondness weights.

In order to control for this issue, we compute the power associated with different specifications of the models. Specifically, we construct data sets by simulation, and test whether these randomly generated data sets satisfy the revealed preference conditions associated with the models. Discriminatory power is then one minus the average pass rate of random data sets. Indeed, the nonparametric conditions should enable us to reject rationality for random, inconsistent choices.

[10] As Ng (1987) argues, a man may offer an expensive ring to his wife, but they may never show this ring to society. This excludes status effects. However, even in this case, the visibility of the ring matters within the household.

While simulating random data sets, we still use some information on the actual choices of singles. Indeed, for each consumer and for each wave, we simulate a new set of budget shares (spent on the 19 commodities) by drawing one set from the distribution of observed sets of budget shares in the sample[11]. These budget shares are then multiplied by the budget associated with the respective consumer and wave, in order to create new commodity bundles. In this way, we create 8100 random data sets. An attractive feature of this so called bootstrap procedure is that the newly generated data sets still reflect a minimal amount of realism. However, since the different choices within one simulated data set do not come from the same individual with identical preferences, these data sets should not satisfy the conditions of our models.

Predictive success In the end, we want to decide on which specification is most attractive in terms of empirical performance, since different characterizations correspond to different diamondness weights. Therefore, we apply the measure of predictive success, proposed by Selten (1991) and discussed in more detail by Beatty and Crawford (2011). An elegant feature of this measure is that it combines pass rates (PR) and discriminatory power (POWER). Predictive success (PS) is defined as:

$$PS = PR + POWER - 1$$

Higher predictive success indicates that the model is better able to distinguish between observed behaviour (which is supposed to be rational according to the model) and random, simulated behaviour (which is supposed to violate the conditions of the model). Hence, a predictive success of 1 would suggest that each observed data set is consistent with the model whereas each random data set violates the conditions of the model. A predictive success of -1 is the worst possible outcome, while a predictive success of 0 would imply that the model cannot discriminate between real and random data sets. The more positive predictive success scores are hence desirable.

6 Results

In this section, we first report the standard pass rates, power and predictive success measures for various specifications of the diamondness weights. We study whether giving higher diamondness weights to the more visible commodities also leads to an improvement of the empirical performance of the economic models. In a further step, we examine the extent to which each individual is behaving consistently with the models while specifically focusing on the time dimension. We also verify whether there is much heterogeneity in the value seeking behaviour of our respondents. Finally, we investigate the heterogeneity in diamondness for the six commodity groups: food at home, vices, food outside home, clothing, fuel and luxuries.

6.1 Pass rates, Power, Predictive success

Table 1 presents the pass rates and power estimates (between brackets) associated with different specifications of the model with pure diamond effects (PDE). The rows represent different values of the diamondness weight associated with food at home and fuel, the columns represent different values of the diamondness weight associated with vices, food outside home, clothing and luxury commodities. A more detailed decomposition of diamondness weights is provided in Subsection 6.4. Remember that, when one particular diamondness weight equals 0, the respective commodity is valued for its intrinsic consumption component only. When, on the other hand, the diamondness weight equals 1, the commodity is specifically valued for its value.

The upper left result in Table 1 corresponds to the classical utility maximization model which can be tested using the GARP (Generalized Axiom of Revealed Preference). The behaviour of about 58 per cent of the

[11]This approach refers to the so called bootstrap power calculation, discussed in Andreoni and Harbaugh, 2006.

	visible goods				
	0	0.25	0.5	0.75	1
less visible goods					
0	0.580	0.605	0.630	0.630	0.667
	(0.491)	(0.484)	(0.476)	(0.470)	(0.468)
0.25	0.630	0.642	0.679	0.679	0.716
	(0.442)	(0.430)	(0.420)	(0.409)	(0.404)
0.5	0.716	0.716	0.741	0.765	0.802
	(0.375)	(0.358)	(0.341)	(0.325)	(0.314)
0.75	0.741	0.753	0.778	0.790	0.852
	(0.288)	(0.260)	(0.233)	(0.206)	(0.188)
1	0.852	0.864	0.889	0.914	1
	(0.184)	(0.145)	(0.106)	(0.061)	(0)

Table 1: Pass rates (and power) for individuals, pure diamond effects

consumers can be rationalized by a classical well-behaved utility function. The lower right result corresponds to the model where all normal and market prices coincide. Not surprisingly, this revealed preference model imposes no testable restrictions, as a result of which all data sets are rationalized. The other cells are more interesting. By varying the diamondness weights, very different pass rates and power estimates are obtained.

	visible goods				
	0	0.25	0.5	0.75	1
less visible goods					
0	0.580	0.617	0.642	0.679	0.741
	(0.491)	(0.474)	(0.457)	(0.439)	(0.424)
0.25	0.753	0.778	0.815	0.852	0.914
	(0.373)	(0.351)	(0.332)	(0.311)	(0.294)
0.5	0.827	0.840	0.864	0.914	0.938
	(0.237)	(0.214)	(0.193)	(0.173)	(0.153)
0.75	0.889	0.901	0.938	0.951	0.988
	(0.118)	(0.093)	(0.070)	(0.053)	(0.040)
1	0.914	0.938	0.963	0.975	1
	(0.058)	(0.036)	(0.017)	(0.005)	(0)

Table 2: Pass rates (and power) for individuals, mixed diamond effects

Table 2 presents the pass rates and power estimates (between brackets) associated with different specifications of the model with mixed diamond effects (MDE). According to this model, preferences are always (at least) defined over an intrinsic consumption component. Depending on the responsiveness of normal prices to market prices (captured by the diamondness weight), value is also taken into account. Similar to Table 1, we observe that the results in the upper left cell coincide with the results of a classical GARP check, whereas the results in the lower right cell reflect the non-testability of the specification. In general, the pass rates in Table 2 are higher than the pass rates in Table 1.

This is explained by the fact that MDE specifications impose less structure on the utility functions. Indeed, even if normal prices coincide with market prices such that utility is derived from the market value of commodities, utility can still be derived from intrinsic consumption components as well.

The results of Tables 1 and 2 are summarized in Tables 3 and 4 in terms of predictive success. On the basis

	visible goods				
	0	0.25	0.5	0.75	1
less visible goods					
0	0.071	0.089	0.106	0.099	0.134
0.25	0.072	0.072	0.099	0.088	0.120
0.5	0.091	0.074	0.082	0.091	0.116
0.75	0.029	0.013	0.011	-0.004	0.039
1	0.035	0.009	-0.005	-0.025	0

Table 3: Predictive success, individuals, pure diamond effects

	visible goods				
	0	0.25	0.5	0.75	1
less visible goods					
0	0.071	0.091	0.099	0.118	0.165
0.25	0.126	0.129	0.147	0.163	0.208
0.5	0.064	0.054	0.057	0.086	0.091
0.75	0.007	-0.006	0.008	0.003	0.028
1	-0.029	-0.025	-0.020	-0.020	0

Table 4: Predictive success, individuals, mixed diamond effects

of these tables, one can study which specifications are empirically supported and which specifications seem more or less unrealistic. In Table 3, the highest predictive success is observed when the diamondness weight associated with food at home and fuel amounts to 0 and the diamondness weight associated with vices, food outside home, clothing and luxury products amounts to 1. In Table 4, the specification with highest predictive success is where the diamondness weight associated with food at home and fuel is 0.25 and the diamondness weight associated with vices, food outside home, clothing and luxury products amounts to 1. Note that, in line with the MDE model, the 0.25-diamondness of food (at home) and fuel does not preclude that utility is derived from the intrinsic consumption of food and fuel.

The figures in Tables 3 and 4 show clearly that the classical model of individual rationality can be improved in terms of predictive success by allowing for pure (improvement by 0.063) and/or mixed (improvement by 0.137) diamond effects. Furthermore, one would be tempted to conclude that especially the more visible commodity groups should get higher diamondness weights, in order to enhance the predictive success. Starting from a maximum predictive success of 0.134 (PDE) or 0.208 (MDE), it seems that giving higher diamondness weights to invisible commodities and lower diamondness weights to visible commodities decreases the predictive success of the models. The highest predictive success scores are situated in the upper right sectors, where food at home and fuel are assumed to have little diamondness and vices, food outside the house, clothing and luxuries are assumed to have considerable diamondness. Finally, the empirical support for the characterizations with mixed diamond effects is somewhat stronger.

One should be careful to draw important conclusions though. First of all, the selected sample includes only 81 consumers. Second, in the immediate neighbourhood of the upper left cell (corresponding to the classical model) in Table 3, there are only minor changes in predictive success as we allow for diamond effects associated with visible or invisible commodities. However, increasing the diamondness weight of food and fuel by a large number seems to deteriorate empirical performance whereas increasing the diamondness weight of vices, food outside home, clothing and luxuries by a large number seems to improve empirical performance.

6.2 Goodness-of-fit

In this paragraph, we provide additional information on the goodness-of-fit of the above specifications. The previously reported pass rates give insight into the fit between the specifications on the one hand and the 81 data sets on the other hand. However, pass rates are robust measures of goodness-of-fit. It remains unknown to what extent each individual consumer behaves consistently with a model, the test only reports 1 (fully rational) or 0 (not rational) per consumer.

Therefore, in Table 5, we report the largest subset of subsequent time periods during which each consumer behaves in line with some specification. For instance, it is possible that a consumer, albeit not fully consistent with some model, behaves consistently with the model during 10 out of 11 waves. Note that Cherchye, De Rock and Vermeulen (2009) and Blundell, Browning and Crawford (2003) also report on the largest number of continuous subperiods satisfying a (revealed preference) test of individual rationality.

individual rationality	mean	std dev	min	max
with $\theta_{lessvis} = 0$ and $\theta_{vis} = 0$	9.9136	1.5427	5	11
with $\theta_{lessvis} = 0$ and $\theta_{vis} = 1$, pure	10.2222	1.3229	6	11
with $\theta_{lessvis} = 0.25$ and $\theta_{vis} = 1$, mixed	10.7901	0.7861	6	11

Table 5: Goodness-of-fit summary statistics, individuals

For reasons of clarity, we only compare three characterizations: 1) the classical model of utility maximization, 2) the PDE specification which has the highest predictive success in Table 3 and finally 3) the MDE specification which has the highest predictive success in Table 4. On average, consumers behave consistently with the classical model during 9.9136 periods. The length of this time period can be increased to 10.2222 when considering pure diamond effects and even 10.7901 when considering mixed diamond effects. The introduction of diamond effects also implies that there are no longer consumers whose choices can not be rationalized for at least 6 periods.

Although this gives more detailed information on the rationality of consumers, one must be careful when comparing the different characterizations on the basis of this information, for we did not take discriminatory power of the models into account in this paragraph.

6.3 Distribution of predictive success

One of the attractive features of the revealed preference methodology is that it allows us to test the rationality of different consumers independently of one another. As such, we can take into account that consumers are heterogeneous in terms of preferences. It is, for instance, not unthinkable that different consumers attribute different diamondness to the same commodity. One particular model can be successful in describing the choices of one consumer while it is unsuccessful in describing the choices of another consumer. Therefore, mean predictive success scores are not fully informative.

In this paragraph, we discuss the predictive success of different specifications for each consumer separately. Table 6 presents the distribution of the predictive success measure across our sample. We report predictive success quartiles for the three characterizations discussed in the previous paragraph: 1) the classical model, 2) the best PDE specification (in terms of average predictive success, see Table 3) and 3) the best MDE specification (in terms of average predictive success, see Table 4).

Before analyzing the results, we see that the median value across the sample, for all specifications, is positive. Positive predictive success implies that a specification is able to distinguish between random (irrational) behaviour and observed (rational) behaviour. We find that the observed choices of at least 50 per cent of the consumers in our sample can be described (and empirically distinguished from random behaviour) by our specifications.

individual rationality	min	first quartile	median	third quartile	max
with $\theta_{lessvis} = 0$ and $\theta_{vis} = 0$	-0.69	-0.3925	0.16	0.4525	0.82
with $\theta_{lessvis} = 0$ and $\theta_{vis} = 1$, pure	-0.7	-0.2725	0.31	0.4425	0.84
with $\theta_{lessvis} = 0.25$ and $\theta_{vis} = 1$, mixed	-0.84	0.1475	0.26	0.4025	0.66

Table 6: Distribution of predictive success

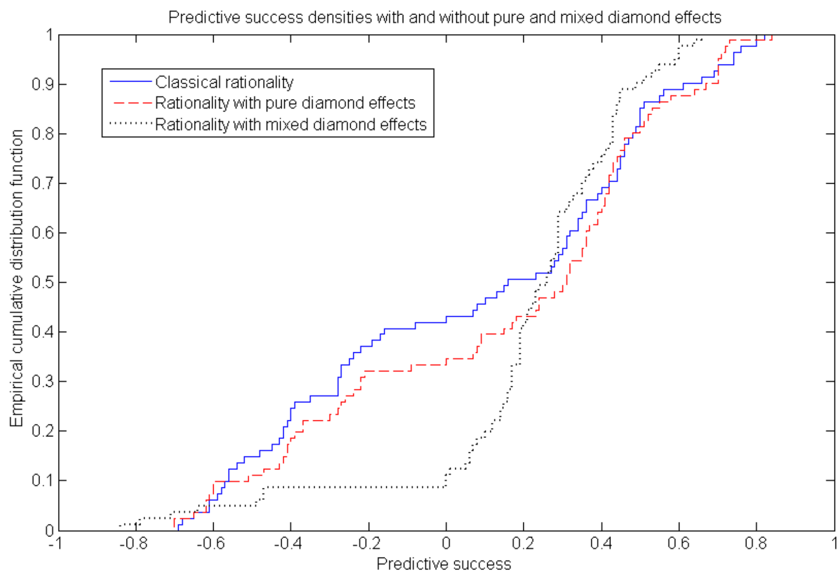

Figure 1: Predictive success distribution for different models

The most apparent finding in Table 6 pertains to the first quartile. The first quartile of the predictive success distribution is negative both for the classical model and for the PDE specification. For the MDE specification, on the other hand, the first quartile is about 0.1475. This implies that the decisions of at least 75 per cent of the respondents in our sample can be described rather well. Figure 1 depicts the empirical (cumulative) distributions of the predictive success associated with the classical model, the PDE specification and the MDE specification under consideration.

From the graph, it can be seen that the classical model has some difficulties in discriminating between real observed choices and random simulated choices. The predictive success associated with the classical model is only positive for about one half of the consumers. By contrast, the predictive success associated with the MDE specification is positive for up to 90 per cent of the respondents. This provides strong empirical support for the case of mixed diamond effects. Moreover, we see that the MDE specification is more likely to obtain positive predictive success scores than the PDE specification. Summarizing, the theoretically more general model with mixed diamond effects is also empirically supported: it describes the choices of many more respondents while it is only slightly more likely to describe random or simulated choices.

Note that we have also recovered different diamondness weights per individual, in order to link individual perceptions of diamondness to individual characteristics, such as age, gender and income. Although we found considerable heterogeneity in diamondness values across the sample, we could not detect significant statistical relationships. This could be due to the relatively small sample size, or to the fact that the results are mainly driven by unobserved heterogeneity.

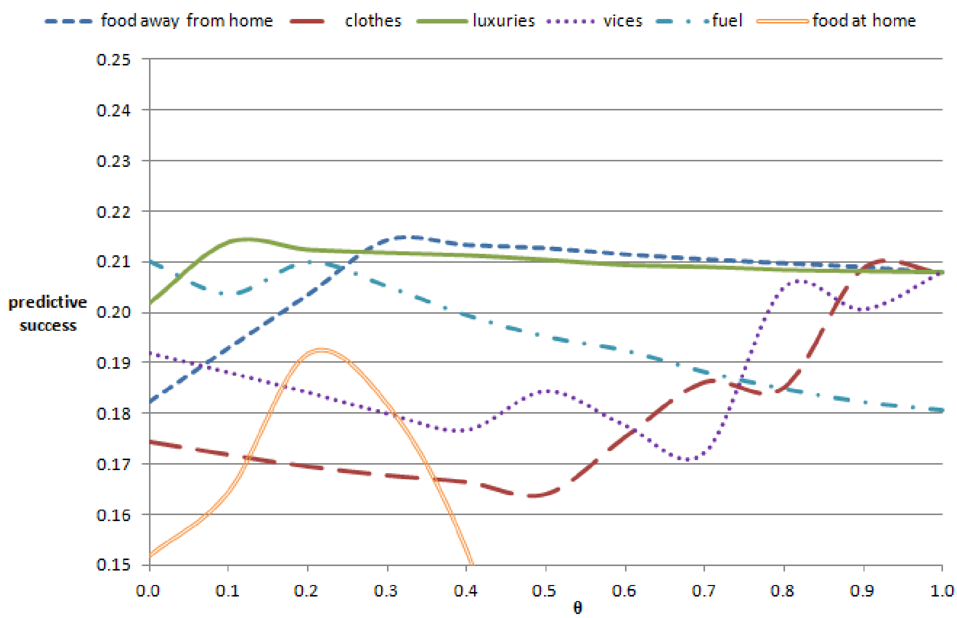

Figure 2: Predictive success in function of diamondness per commodity (benchmark = best performing specification with mixed diamond effects)

6.4 Diamondness per commodity

Up to now, we have identified aggregate diamondness weights for the visible and less visible group of commodities. We finally go one step further by splitting these subgroups back up in food at home, fuel, vices, food away from home, clothing and luxuries. Per product, we will analyze the evolution of the predictive success measure in function of the commodity's perceived diamondness weight.

It is important to note that we use the best performing specification in Table 4 (mixed diamond effects) as the benchmark. Because we aim at analyzing the diamondness of each commodity separately, we fix the diamondness of the other commodities to the values which correspond to the benchmark specification ($\theta_{lessvis} = 0.25$ and $\theta_{vis} = 1$). For robustness, we repeat this exercise in Appendix C for an alternative benchmark[12].

The following table summarizes predictive success for different values of the diamondness weights.

Clearly, there is considerable heterogeneity in the evolution of the predictive success across the different commodities. First of all, it is confirmed that giving high diamondness weights to the less visible goods - *food consumption at home* and *fuel* - is detrimental to the empirical performance of the model. Increasing the postulated diamondness of fuel and food consumed at home (more than $\theta_{food} = 0.2$) leads to a substantial decrease in the estimated predictive success. Interestingly, the predictive success reacts differently to the diamondness of *food consumption away from home*. There seems to be a positive relationship between the predictive success of some specification and the postulated diamondness of restaurant visits.

Second, predictive success is increasing in the postulated diamondness of *clothes* and *vices* (alcohol and tobacco), although the relationship between empirical performance on the one hand and postulated diamondness on the other hand appears to be volatile. The predictive success initially decreases as higher dia-

[12]In Appendix C, we no longer compare our results based on the best performing specification in Table 4. Instead, we compare our results on the basis of the classical model. This means that the evolution of the predictive success in function of the diamondness of one product is analyzed when the diamondness of all other products is (assumed to be) 0.

mondness is attributed to alcohol and tobacco (a minimum is reached at $\theta_{vices} = 0.7$). However, one can observe a steep increase in predictive success after this point. It is not unthinkable that there are two kinds of people when it comes to vices: people who only care for the intrinsic consumption component of alcohol and tobacco (possibly addicted consumers - a habits model could be used to distinguish these people) and on the other hand people who appreciate expensive wine/beers/cigares for their value, etc.

Finally, note that the predictive success in function of the diamondness of *luxuries* remains more or less constant across all possible values of the diamondness weight. Only the case where $\theta_{lux} = 0$ has a somewhat lower predictive success.

Summarizing, these more refined results seem to confirm what was found in Subsection 6.1: the reaction of predictive success to changes in the diamondness parameters clearly depends on the goods under consideration. Different commodities do not necessarily have the same degree of diamondness.

7 Conclusion

In this paper, we develop an easily testable (revealed preference) model for rational consumption in the presence or absence of diamond effects. In this way, we try to incorporate psychological insights into economic modelling. Our model is general in the sense that both the classical utility maximization model, the models of Ng (1987 and 1993) - where only one of the commodities is a so-called diamond good - and the model which loses its testable implications because the preferences depend on the market prices of all commodities, are different specifications of the same underlying model. This general model can easily be modified to capture pure diamond effects (high responsiveness of normal to market prices excludes that utility is derived from intrinsic consumption) and mixed diamond effects (normal prices can be very responsive to market prices while utility is still derived from the intrinsic consumption component as well).

From an empirical perspective, we make use of the Russian Longitudinal Monitoring Survey (RLMS) which provides data on various consumption choices. The commodities are heterogeneous in terms of visibility to society. Clothing and luxuries, for instance, are more visible commodities than food at home or fuel. By using the empirical success (taking into account both pass rates and discriminatory power) of a model as a criterion, we are able to identify the specification which describes reality most accurately. Different specifications of a model are pinned down using a set of diamondness weights, which define the extent to which the arguments entering the utility functions of consumers depend on the market prices of commodities.

Our results suggest that, in general, the predictive success associated with the classical model of utility maximization can be improved by increasing the diamond weights of the more visible commodities. First, this suggests that incorporating diamond effects into models of rationality improves the empirical performance of the models. Second, in line with Heffetz (2011), it is confirmed that the more visible commodities are more likely to trigger diamond (status) effects.

Future research could focus on the following extensions. First of all, although our results based on a small sample are already quite interesting, it would be better to test the aforementioned models using larger data sets. Second, to distinguish the diamond effects (Ng, 1987 and 1993) from status effects (Veblen, 1899) and quality effects (Scitovsky, 1945), one should control for the budget sets of other consumers in society and control for the quality of the commodities. Third, although we are able to identify sets of diamondness weights which satisfy the rationality criterion, it is difficult to pin down an exact value for the diamondness parameter associated with some individual. Finally, future research could also concentrate on integrating the diamond effects in revealed preference models of collective consumption. In collective settings, e.g. household decisions, various other factors (such as the love between two partners) may affect consumption of diamond goods.

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A Proofs

A.1 Proof of Proposition 6

Proof.

- We first prove that condition 1 implies condition 2. Consider the following (necessary) first-order condition for the optimization of PDE:

$$U_{\delta^n Q^n} * \delta^n \leq \lambda P^n;$$

where $U_{\delta^n Q^n}$ is a subderivative of the (concave) utility function with respect to $\delta^n Q^n$. Concavity of the utility function gives:

$$u_t - u_v \leq \sum^n U_{\delta^n Q^n, v} * (\delta_t^n Q_t^n - \delta_v^n Q_v^n);$$

Substituting $U_{\delta^n Q^n, v}$ by means of the first-order condition finally yields:

$$u_t - u_v \leq \lambda_v \sum^n P_v^n / \delta_v^n * (\delta_t^n Q_t^n - \delta_v^n Q_v^n);$$

- We then prove that condition 2 implies condition 1.

  We start from the observation that

$$U(\delta\mathbf{Q}) \leq U_v + \lambda_v \sum^n P_v^n/\delta_v^n * (\delta^n Q^n - \delta_v^n Q_v^n);$$

  In a following step, we select the minimum of all overestimates:

$$U(\delta\mathbf{Q}) = \min_v (U_v + \lambda_v \sum^n P_v^n/\delta_v^n * (\delta^n Q^n - \delta_v^n Q_v^n));$$

  This formulation should be such that any $(\delta_t\mathbf{Q})$, for which $\mathbf{P}_t\mathbf{Q}_t \geq \mathbf{P}_t\mathbf{Q}$, implies that $U(\delta_t\mathbf{Q}_t) \geq U(\delta_t\mathbf{Q})$.

  First, it is important to understand that $U(\delta_v\mathbf{Q}_v) = U_v$ for $v = 1, ..., T$. Indeed, for some t, we have that

$$\begin{aligned} U(\delta_v\mathbf{Q}_v) &= U_t + \lambda_t \sum^n P_t^n/\delta_t^n * (\delta_v^n Q_v^n - \delta_t^n Q_t^n) \\ &\leq U_v + \lambda_v \sum^n P_v^n/\delta_v^n * (\delta_v^n Q_v^n - \delta_v^n Q_v^n) = U_v \end{aligned}$$

  If this inequality were strict, we would have that

$$U_v - U_t > \lambda_t \sum^n P_t^n/\delta_t^n * (\delta_v^n Q_v^n - \delta_t^n Q_t^n)$$

  which contradicts the Afriat inequalities. Hence $U(\delta_v\mathbf{Q}_v) = U_v$.

  Second, any $(\delta_t\mathbf{Q})$ for which $\mathbf{P}_t\mathbf{Q}_t \geq \mathbf{P}_t\mathbf{Q}$ must be consistent with

$$\begin{aligned} U(\delta_t\mathbf{Q}) &= \min_v (U_v + \lambda_v \sum^n P_v^n/\delta_v^n * (\delta_t^n Q^n - \delta_v^n Q_v^n)) \\ &\leq U_t + \lambda_t \sum^n P_t^n/\delta_t^n * (\delta_t^n Q^n - \delta_t^n Q_t^n) \leq U_t = U(\delta_t\mathbf{Q}_t) \end{aligned}$$

  The first inequality follows from the definition of $U(\delta_t\mathbf{Q})$, the second inequality follows from

$$\begin{aligned} & \lambda_t \sum^n P_t^n/\delta_t^n * (\delta_t^n Q^n - \delta_t^n Q_t^n) \leq 0 \\ \Rightarrow \quad & \lambda_t \sum^n P_t^n * (Q^n - Q_t^n) \leq 0 \end{aligned}$$

■

A.2 Proof of Proposition 8

Proof.

- We first prove that condition 1 implies condition 2. Consider the following (necessary) first-order condition for the optimization of MDE:

$$U_{Q^n} + U_{\delta^n Q^n} * \delta_t^n \leq \lambda P_t^n;$$

where U_{Q^n} and $U_{\delta^n Q^n}$ are subderivatives of the (concave) utility function with respect to Q^n and $\delta^n Q^n$, respectively. Concavity of the utility function gives:

$$u_t - u_v \leq U_{Q^n,v} * (Q_t^n - Q_v^n) + \sum^n U_{\delta^n Q^n,v} * (\delta_t^n Q_t^n - \delta_v^n Q_v^n);$$

Finally, we replace $\mathfrak{p}_v^n = U_{Q^n,v}$ and $\mathfrak{P}_v^n = [\lambda P_t^n - U_{Q^n,v}]/\delta_t^n$ such that $\mathfrak{P}_v^n \geq U_{\delta^n Q^n,v}$.

$$u_t - u_v \leq \sum^n \mathfrak{p}_v^n * (Q_t^n - Q_v^n) + \sum^n \mathfrak{P}_v^n * (\delta_t^n Q_t^n - \delta_v^n Q_v^n);$$
$$\lambda_v P_v^n = \mathfrak{p}_v^n + \mathfrak{P}_v^n * \delta_v^n \quad \forall n \in N;$$

- We then prove that condition 2 implies condition 1 (based on Varian, 1982).

  We start from the observation that

$$U(\mathbf{Q}, \delta\mathbf{Q}) \leq U_v + \sum^n \mathfrak{p}_v^n * (Q^n - Q_v^n) + \sum^n \mathfrak{P}_v^n * (\delta^n Q^n - \delta_v^n Q_v^n);$$

  In a following step, we select the minimum of all overestimates:

$$U(\mathbf{Q}, \delta\mathbf{Q}) = \min_v (U_v + \sum^n \mathfrak{p}_v^n * (Q^n - Q_v^n) + \sum^n \mathfrak{P}_v^n * (\delta^n Q^n - \delta_v^n Q_v^n));$$

  This formulation should be such that any $(\mathbf{Q}, \delta_t\mathbf{Q})$, for which $\mathbf{P}_t\mathbf{Q}_t \geq \mathbf{P}_t\mathbf{Q}$, implies that $U(\mathbf{Q}_t, \delta_t\mathbf{Q}_t) \geq U(\mathbf{Q}, \delta_t\mathbf{Q})$.

  First, it is important to understand that $U(\mathbf{Q}_v, \delta_v\mathbf{Q}_v) = U_v$ for $v = 1, ..., T$. Indeed, for some t, we have that

$$\begin{aligned} U(\mathbf{Q}_v, \delta_v\mathbf{Q}_v) &= U_t + \sum^n \mathfrak{p}_v^n * (Q_v^n - Q_t^n) + \sum^n \mathfrak{P}_v^n * (\delta_v^n Q_v^n - \delta_t^n Q_t^n) \\ &\leq U_v + \sum^n \mathfrak{p}_v^n * (Q_v^n - Q_v^n) + \sum^n \mathfrak{P}_v^n * (\delta_v^n Q_v^n - \delta_v^n Q_v^n) \\ &= U_v \end{aligned}$$

  If this inequality were strict, we would have that

$$U_v - U_t > \sum^n \mathfrak{p}_v^n * (Q_v^n - Q_t^n) + \sum^n \mathfrak{P}_v^n * (\delta_v^n Q_v^n - \delta_t^n Q_t^n)$$

  which contradicts the Afriat inequalities. Hence $U(\mathbf{Q}_v, \delta_v\mathbf{Q}_v) = U_v$.

  Second, any $(\mathbf{Q}, \delta_t\mathbf{Q})$ for which $\mathbf{P}_t\mathbf{Q}_t \geq \mathbf{P}_t\mathbf{Q}$ must be consistent with

$$\begin{aligned} U(\mathbf{Q}, \delta_t\mathbf{Q}) &= \min_v (U_v + \sum^n \mathfrak{p}_v^n * (Q^n - Q_v^n) + \sum^n \mathfrak{P}_v^n * (\delta_t^n Q^n - \delta_v^n Q_v^n)) \\ &\leq U_t + \sum^n \mathfrak{p}_v^n * (Q^n - Q_t^n) + \sum^n \mathfrak{P}_v^n * (\delta_t^n Q^n - \delta_t^n Q_t^n) \\ &\leq U_t = U(\mathbf{Q}_t, \delta_t\mathbf{Q}_t) \end{aligned}$$

  The first inequality follows from the definition of $U(\mathbf{Q}, \delta_t\mathbf{Q})$, the second inequality follows from

$$\begin{aligned} & U_t + \sum^n \mathfrak{p}_v^n * (Q^n - Q_t^n) + \sum^n \mathfrak{P}_v^n * (\delta_t^n Q^n - \delta_t^n Q_t^n) \\ = \; & U_t + \sum^n (\lambda_t P_t^n - \partial U_t / \partial(\delta_t^n Q_t^n) * \delta_t^n) * (Q^n - Q_t^n) + \sum^n \mathfrak{P}_v^n * (\delta_t^n Q^n - \delta_t^n Q_t^n) \\ = \; & U_t + \lambda_t \sum^n P_t^n * (Q^n - Q_t^n) \\ \leq \; & U_t \end{aligned}$$

■

B General and nonlinear normal price function

In this appendix, we allow for a more general normal price function $\delta_t^{n\prime} = \delta(P_1^n, ..., P_t^n)$. First of all, the normal prices can depend on the market prices in the current period *and* in *all* observed past periods. Second, the relationship between normal prices and market prices is no longer linear. Hence, the responsiveness of normal to market prices, and hence the diamondness weights, are no longer required to be constant.

Definition 9 *The normal price $\delta_t^{n\prime}$ of commodity n in observation t is a function of all market prices P_v^n of commodity n such that $v \leq t$. This function is*

1. *non-decreasing in all P_v^n,*
2. *homogeneous of degree 1 in all P_v^n.*

The diamondness per commodity and per observation is then given by a vector $\theta^n = \nabla_{P^n}\delta(P_1^n, ..., P_t^n)$. It can easily be seen that all our propositions remain valid. The only difference is the specification of the normal price function. The linear expression is now replaced by a more general function $\delta_t^{n\prime} = \delta(P_1^n, ..., P_t^n)$ which is, yet, restricted by the above conditions. Note that the innovation associated with the introduction of this general normal price function is not limited to the non-linear relationship between normal and market prices. It is also reflected in the number of (past) periods which impact on the normal prices.

Suppose one imposes a linear normal price function which depends on market prices in the current period and in *all* observed past periods: $\delta_t^{n\prime} = \theta_0^n * P_t^n + ... + \theta_{t-1}^n * P_1^n$. Then θ_0^n is the immediate responsiveness of normal to market prices, whereas θ_{t-1}^n is the responsiveness of normal to market prices delayed by $t-1$ periods. In this way, the model can also deal with situations where different goods have different memory coefficients, as discussed by Pollak (1977). Indeed, the normal prices of some commodities may be more sensitive to market prices in the recent past whereas the normal prices of other goods may be more dependent on the market prices of earlier periods.

C Diamondness per commodity: robustness

To obtain more (robust) insight into the diamondness of different commodity groups, we also analyze the evolution of predictive success in function of the diamondness of some commodity, while assuming that the diamondness of all other commodity groups is 0. Previously, we used an 'optimal' benchmark, where the diamondness of the other commodities was taken from the scenario with highest predictive success in Table 4.

Figure 3 presents the evolution of predictive success in function of the diamondness of some commodity, with the classical model of utility maximization as the benchmark.

Most of our earlier conclusions remain valid. The predictive success decreases as the diamondness of *fuel* is increased or when the diamondness of *food consumption at home* is increased more than 0.2. Moroever, the predictive success increases as the diamondness of *clothes, vices* and *food consumption away from home* is raised. The predictive success is rather insensitive to changes in the diamondness of *luxuries*.

Interestingly, Figure 3 also confirms that, according to the model with mixed diamond effects, the diamondness of food consumed at home is not exactly 0. This was also observed in the predictive success results of Table 4.

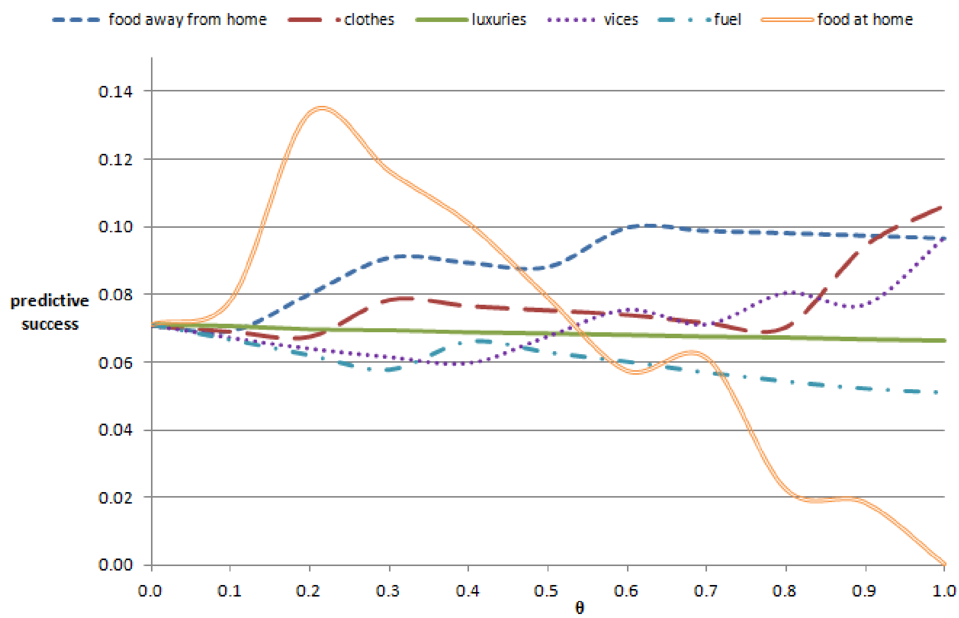

Figure 3: Predictive success in function of diamondness per commodity (benchmark = classical model)