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Measuring the Efficiency of VAT reforms: Evidence from Slovakia

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Abstract

We estimate a demand system to simulate the welfare and fiscal impacts of the recent value added tax (VAT) cut on selected foods in Slovakia. We evaluate the efficiency of the tax cut vis-à-vis its hypothetical alternatives using the ratio of the welfare and fiscal impacts. Based on our findings, tax cuts tend to be more efficient if demand for a good is price-elastic or if the good has several complements. The results also indicate that cherry-picking from food sub-categories could have improved the efficiency of the recent tax change. Further, we found potential revenue-neutral welfare-improving tax schemes, namely, a reduced rate on foods financed by an increased rate on non-foods improves welfare in case of most food types. The paper contributes to the literature by demonstrating that standard approximate efficiency indicators of VAT reforms are biased compared with simulation-based results for any plausible degree of a tax change.

JEL classification: D12; E21; H21; I31.
Key words: Consumer behavior; Demand system; QUAIDS; Value added tax; Tax reform; Efficiency; Optimal taxation; Slovakia.

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NON-TECHNICAL SUMMARY

Using Slovak household-level data, we estimate a demand model for eight groups of food products and a non-food consumption aggregate. The structure of the model is motivated by the recent VAT change in Slovakia in 2016. This new policy reduced the standard rate of 20% to 10% for selected foods, including bread, milk, butter and unprocessed meat. The government's aim was to subsidize the consumption of basic foods and to support domestic food production.

We simulate demand responses to the VAT cut by using the estimated model. This allows us to quantify the impact of the VAT cut on consumer welfare and fiscal revenues at the household level. Next, we apply the ratio of the welfare and fiscal effects as an efficiency indicator. This reflects the amount of welfare gained for a unit of fiscal revenues sacrificed by the government, which we call marginal welfare gain (MWG). Apart from the actual VAT change, we also examine the efficiency of hypothetical tax cuts for each consumption bundle in our model. We find that the efficiency of a tax cut is higher if demand for a good is price-elastic or if the good has several complements in the consumption basket. The above exercise demonstrates that cherry-picking from food sub-categories could have improved the efficiency of the Slovak VAT cut.

As our main contribution to the literature, we use simulated rather than approximate measures of the welfare and fiscal impacts. To the best of our knowledge, the former approach has not been applied in the context of efficiency evaluations of indirect tax reforms. In this work, we prove that the standard approximate measures lead to a biased efficiency ranking of alternative policies. The bias can be attributed to the fact that demand responses, e.g. substitution effects, are ignored by the approximate welfare impact, whereas the approximate fiscal impact is based on price elasticities to predict demand responses. The latter measure, however, can be imprecise in case of the non-linearity of the model and non-incremental changes in taxes.

Ranking goods based on the efficiency of potential tax changes relates to theories of optimal indirect taxation. According to the literature, estimating the optimal VAT scheme is not feasible. Instead, it would be better to look for revenue-neutral tax reforms that improve welfare vis-à-vis the status quo. This could be achieved by cutting the VAT on goods associated with a high MWG while simultaneously increasing the VAT on goods with a low MWG. The above approach could gradually lead to the realization of an optimal VAT scheme at no fiscal costs. We contribute to this field with evidence of potential revenue-neutral welfare-improving tax reforms in the case of Slovakia. However, we also find that revenue-neutral welfare impacts are fairly small, reaching at most 1.5% of the average household's total consumption expenditures.

The hypothetical revenue-neutral tax reforms we studied depart from the homogenous VAT scheme by introducing a reduced rate on selected foods and an increased rate on non-food. We also find that welfare improvements are feasible for most food bundles in our model. This result is in line with the predictions of the previously constructed efficiency ranking. Specifically, welfare improvements are attainable only for those kinds of foods, that have a higher MWG than the financing bundle of non-foods. Furthermore, we also find that fiscally neutral welfare improvements can be achieved in case of a reduced rate on all foods, but not for the basic ones subsidized by the recent VAT cut in Slovakia.

Overall, we can conclude that using a demand model to rank commodities according to their MWGs can be helpful for countries that aim to design efficient VAT reforms. In particular, such a ranking can provide guidance for cherry-picking among closely related products that are considered in an indirect tax reform. Moreover, the ranking can provide guidance for identifying revenue-neutral welfare-improving tax reforms.

1. INTRODUCTION

Consumption taxes not only represent a significant source of tax revenues in developed countries, they also typically have the highest share compared with other types of taxes. Their share averages around one third in the Organization for Economic Co-operation and Development (OECD) countries, slightly dominating the second largest source, namely, personal income taxes (Decoster et al., 2010).

The optimal tax structure has been extensively discussed in the literature, specifically from the equity and efficiency perspectives. Several papers addressed the choice between direct versus indirect taxes.[3] On the one hand, Atkinson and Stiglitz (1976) conclude that (progressive) income taxes are effective and sufficient tools for pursuing equity and efficiency goals, thus rendering indirect taxes unnecessary. On the other hand, a typical argument in favor of consumption taxes suggests taxing negative externalities, such as alcohol, tobacco, unhealthy food, or pollution. Moreover, taxing consumption can be viewed as equivalent to taxing leisure, which is less distortive for production than taxing labor or income (see e.g. Bosch and van den Noord, 1990).

A related stream of the literature considered the optimal structure of consumption taxes (see Crawford et al., 2010, for a comprehensive overview). Among others, Atkinson and Stiglitz (1980) suggest that taxing goods with a price-elastic demand has the greatest impact on changing consumer behavior. Therefore, consumers incur a larger deadweight loss, which in turn, leads to a more severe allocative inefficiency. Given that price elasticities vary across commodities, a differentiated tax scheme that reflects demand characteristics could be more efficient than applying a unified rate.

The above conclusion seems to be in line with the common practice in Europe, as de facto no European Union (EU) country applies a unified VAT scheme.[4] Accordingly, EU countries typically assign a reduced rate to necessities (e.g. food, clothing, housing or health care), services related to culture and education, services of small businesses (e.g. hotels, restaurants and household services) and agricultural inputs.[5] Meanwhile, from a global perspective, developed countries are more likely to apply a differentiated indirect tax scheme compared with less developed ones.[6] The above tendency may be related to the higher administrative costs of maintaining a differentiated consumption tax scheme and to the lack of effective policy recommendations based on research results in less developed countries.

Estimating the optimal structure of consumption taxes is generally not plausible in practice. Hence, Ahmad and Stern (1984) directed the academic discussion toward marginal tax reforms,[7] with the aim of identifying incremental changes in a tax system that are welfare-improving and have a neutral effect on fiscal revenues. Such findings could indicate efficient directions of changes in the prevailing tax system. For this purpose, there is a need to initially rank goods based on the welfare loss due to an extra unit of tax revenues raised from them. The ranking then provides guidance for cutting the tax rate on a socially costly good and neutralizing

[3]The seminal contributions to this discussion came from Ramsey (1927) and Diamond and Mirrlees (1971a,b).

[4]Perhaps Denmark's VAT scheme is the closest to a homogenous one. According to the European Commission, Denmark applies a zero rate to a small share of consumption, i.e., "sales of newspapers normally published at a rate of more than one issue per month" and a standard rate of 25% is levied from the rest of consumption.

[5]Source: European Commission.

[6]Based on our calculations using the Global Indirect Tax Rates database of Deloitte Touche Tohmatsu Ltd., only about 12% of high-income countries have a homogenous tax scheme, as opposed to low-income countries, where the same share reaches 48%.

[7]For a survey of the more recent literature on marginal tax reforms see Santoro (2007).

the revenue loss by a tax increase on a less costly taxed good.

The efficiency ranking of goods based on the work of Ahmad and Stern (1984) requires detailed household-level consumption data, which can then be used to estimate the price elasticities of demand for the goods being considered. The elasticities are typically obtained by fitting a demand system. Most applications estimate the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980), or its quadratic extension (QUAIDS) introduced by Banks et al. (1997). A non-exhaustive list of applications following Ahmad and Stern (1984) includes Cragg (1991) for Canada, Decoster and Schokkaert (1989, 1990) for Belgium, Kaiser and Spahn (1989) for Germany, Kaplanoglou and Newbery (2003) for Greece, Madden (1995, 1996) and Savage (2016) for Ireland, Urakawa and Oshio (2010) for Japan and South Korea, and Urzúa (2005) for Mexico.

We contribute to the above literature by proposing an improved estimation of the efficiency ranking. The existing papers rely on first-order approximations of the welfare impact and use price elasticities to estimate the fiscal impact. In our work, we show that the efficiency indicator - as a ratio of the above two proxies - leads to a biased ranking of goods. The bias can be attributed to the fact that the approximate welfare impact ignores demand responses. Therefore welfare impacts estimated from a demand model are preferable (see Banks et al., 1996). In turn, the bias of the approximate fiscal impact follows from using price elasticities and those may differ from the impacts simulated from a demand model (e.g., the non-linear QUAIDS we use), especially if the tax change is non-incremental.[8] As an additional contribution, we provide evidence of potential revenue-neutral and welfare-improving VAT changes in Slovakia. However, we find that such welfare impacts are rather small.

In the current paper, we use Slovak household-level data and apply a QUAIDS for eight food bundles and a non-food consumption aggregate using. The structure of the model is motivated by the recent VAT change in Slovakia in 2016, which reduced the standard rate of 20% to 10% for selected food products, including bread, milk, butter, and unprocessed meat. The government's aim was to subsidize the consumption of basic foods as well as to support domestic food production.

The rest of the paper is organized as follows. Section 2 is devoted to the theoretical framework. Section 3 describes our dataset. Section 4 deals with estimation issues. Section 5 presents simulation results, and the final section concludes this work.

2. Theoretical Framework

2.1 The Quadratic Almost Ideal Demand System

Similar to our study, recent demand system applications typically follow the Quadratic Almost Ideal Demand System (QUAIDS) introduced by Banks et al. (1997).[9] It is the quadratic extension of Deaton and Muellbauer (1980)'s Almost Ideal Demand System (AIDS). Banks et al. (1997) argue for the inclusion of an additional quadratic log-expenditures term in the budget share equations in order to provide sufficient flexibility for Engel curves. Such an extended

[8] See Janský (2014) for an application of QUAIDS to simulate the fiscal impacts of a VAT reform in the Czech Republic.

[9] Other common demand systems for modeling the allocation of expenditures, given a fixed budget constraint, include the Linear Expenditure System (LES) (Stone, 1954), the Rotterdam model (Barten, 1964), or the Indirect Translog System (ITS) (Christensen et al., 1975).

functional form is consistent with empirical observations, as it allows a luxury good to become a necessity (or vice versa) as one's income rises. Using the notation of Banks et al. (1997), let the preferences of households $h = 1, ..., H$ follow the indirect utility function given by

$$\ln V = \left\{ \left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1}, \tag{1}$$

where m denotes total nominal expenditures, p is a price vector associated with goods $i = 1, ..., n$, and $\ln a(p)$ is a translog aggregator of the prices of n goods and is defined as

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j, \tag{2}$$

while $b(p)$ represents the Cobb-Douglas price aggregator

$$b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \tag{3}$$

and $\lambda(p)$ is defined as

$$\lambda(p) = \sum_{i=1}^{n} \lambda_i \ln p_i, \tag{4}$$

where $\sum_i \lambda_i = 0$. Note that $\lambda(p)$ drives the quadratic extension of the AIDS model. Hence, it follows that, if $\lambda(p) = 0$, the indirect utility function can be simplified to $\frac{\ln m - \ln a(p)}{b(p)}$, as in AIDS.

The following set of restrictions is imposed in order to keep consistency with microeconomic theory and to reduce the number of parameters to be estimated. The adding-up property of demand systems requires that

$$\sum_{i=1}^{n} \alpha_i = 1; \sum_{i=1}^{n} \beta_i = 0; \sum_{i=1}^{n} \lambda_i = 1; \sum_{i=1}^{n} \gamma_{ij} = 0. \tag{5}$$

Homogeneity of degree zero in prices and income requires that

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \quad \forall j, \tag{6}$$

The symmetry restriction of the Slutsky matrix is given by

$$\gamma_{ij} = \gamma_{ji}. \tag{7}$$

By applying Roy's identity to the indirect utility function in Equation (1), one can express a set of n budget share equations as

$$w_i = \alpha_i + \sum_{j=1}^{n} \ln p_j + \beta_i + \ln \left[\frac{m}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left\{ \ln \left[\frac{m}{a(p)} \right] \right\}^2, \tag{8}$$

which can be subsequently estimated by using cross-sectional household expenditures data. Once again, note that in the special case when $\lambda_i = 0$, the last (quadratic) term in (8) vanishes and w_i becomes a linear function of log-real expenditures, as in the AIDS model.

Using the budget share equations above, we can derive the budget- and price elasticities of the consumption bundles comprising the model. Following Banks et al. (1997), demand elasticities can be computed by partially differentiating the budget share Equation (8) with respect to $\ln m$ and $\ln p_j$ as

$$\mu_i \equiv \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\lambda_i}{b(p)} \left\{ \ln \left[\frac{m}{a(p)} \right] \right\} \tag{9}$$

and

$$\mu_{ij} \equiv \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i \left(\alpha_j + \sum_k \gamma_{jk} \ln p_k \right) - \frac{\lambda_i \beta_j}{b(p)} \left\{ \ln \left[\frac{m}{a(p)} \right] \right\}^2 . \tag{10}$$

Consequently, the expenditure elasticities become

$$e_i = \mu_i / w_i + 1. \tag{11}$$

Next, the uncompensated price elasticities are defined as

$$e^u_{ij} = \mu_i / w_i - \delta_{ij}, \tag{12}$$

where δ_{ij} is Kronecker's delta being equal to 1 if $i = j$ and 0 otherwise. Finally, the compensated price elasticities are computed from the Slutsky equation using the formula

$$e^c_{ij} = e^u_{ij} + e_i w_j. \tag{13}$$

Note that the above expressions of budget- and price elasticities are non-linear functions of log expenditures and prices. Hence, approximative analysis using the sample mean elasticities may generate different (or even biased) results compared with simulations based on the budget share equations of the model.

2.2 Marginal welfare gains from a VAT cut

Using the demand system (1) - (8) we can model VAT changes as exogenous price changes and proceed to quantifying the associated demand response. This allows for the simulation of the impact of tax changes on welfare and fiscal revenues at the household level. Let us assume a proportional VAT rate t, which relates consumer prices p observed by households to producer prices p^0 as

$$p = p^0(1 + t). \tag{14}$$

Suppose a tax change, which reduces the standard VAT rate t^s_i for commodity i to t^r_i, i.e., $0 \leq t^r_i \leq t^s_i$. Assuming fixed producer prices, i.e., a perfect pass-through of tax changes to consumer prices,[10] the consumer price p_i changes by the ratio

$$\tau_i \equiv \frac{1 + t^r_i}{1 + t^s_i} < 1. \tag{15}$$

The resulting difference in tax revenues, $\Delta R\left(p_i \tau_i, p_{-i}\right)$, which is collected from each household h, can thus be written as[11]

$$\Delta R\left(p_i \tau_i, p_{-i}\right) = (\tau_i - 1) m w_i (p_i \tau_i, p_{-i}), \tag{16}$$

[10] The extent to which producers may pass on the tax change to consumer prices is discussed in more detail in Section 5.

[11] $R(p_i\tau, p_{-i}) - R(p) = \frac{t_r}{1+t_s} m w_i(p_i\tau, p_{-i}) + \frac{t_s}{1+t_s} m \left[1 - w_i(p_i\tau, p_{-i})\right] - \frac{t_s}{1+t_s} m$

where p_{-i} are prices of bundles other than i. Here, ΔR_i becomes negative as tax revenues are expected to drop after a tax cut.

Next, the impact of an exogenous price change on consumer welfare is measured in monetary terms as the compensating variation.[12] The compensating variation is defined as the amount of cash transfer a household would need to receive after a price change so that it could reach its initial utility level prior to the price change. In other words, it is a nominal version of the income effect. Another alternative indicator of the welfare effect could be the one based on the change in indirect utility expressed from (1), although this is defined in units of real consumption. Given that we aim to relate the welfare impact to nominal fiscal revenues, assuming the compensating variation as the welfare impact is more appropriate. Accordingly, the compensating variation of a price change in p_i by τ_i, given initial utility level v_0, can be written as

$$\Delta W_i\left(p_i\tau_i, p_{-i}\right) = m(p_i, p_{-i}, v_0) - m(p_i\tau_i, p_{-i}, v_0), \tag{17}$$

where total expenditures, $m(p, v_0)$, can be expressed from the indirect utility function (1) as below.

$$m(p, v_0) = \exp\left(\ln a(p) + \frac{b(p)\ln v_0}{1-\lambda(p)\ln v_0}\right) \tag{18}$$

The initial utility level before the price change, v_0, is computed from (1) using the estimated parameters of (2) - (4).

Next, we construct a household-specific indicator of marginal welfare gains (MWG)[13] with the aim of comparing the efficiency of different tax cuts. We define this as the ratio of ΔW_i and $-\Delta R_i$ representing the gain in household welfare for a unit of fiscal revenues sacrificed by the government. The ratio is a function of the rate of tax change and is given by

$$MWG(\tau_i) = -\frac{\Delta W_i(\tau_i)}{\Delta R_i(\tau_i)}. \tag{19}$$

In order to aggregate the abovementioned household-level indicator to the social level, we must assume a social welfare function that assigns certain social weights to each household. For simplicity, we follow a utilitarian social welfare function with equal weights, which implies that the aggregate-level indicator of marginal welfare gains is simply the sample average. As we will show in Section 5.3 below, our results are not sensitive to equity considerations and to our assumption of unified social weights.

We can follow the approach of Ahmad and Stern (1984) as an alternative indicator of MWG[14]. The authors define their indicator on the aggregate level as

$$MWG_i^{AS} = -\frac{\partial U/\partial t_i}{\partial R/\partial t_i} = \frac{\sum_{h=1}^{H}\theta^h m^h w_i^h}{M_i + \sum_{k=1}^{N}\frac{M_k e_{ki}^u t_k}{1+t_k}}, \tag{20}$$

where U is a social welfare function of indirect utilities V^h for the population of households $h = 1, ..., H$

$$U = U\left[V^1\left(m^1, p\right), ..., V^H\left(m^H p\right)\right]. \tag{21}$$

Further, θ^h in the nominator of (20) is the social marginal utility of income of household h, or the household's weight in social welfare. Welfare weight θ^h is treated as a parameter in the literature

[12] The concept was introduced by Hicks (1939) and was applied in the context of QUAIDS by Banks et al. (1996, 1997).

[13] In case of VAT hikes we would call it the marginal welfare loss (MWL).

[14] Note that Banks et al. (1996) show this alternative measure to be biased

and is usually specified in terms of total expenditure per equivalent adult of a household, I_h, relative to the same indicator for the poorest household in the population (sample), I_1.

$$\theta^h = \left(\frac{I_1}{I_h}\right)^\varepsilon, \tag{22}$$

where ε is a non-negative parameter of inequality aversion. In order to maintain the comparability of our MWG indicator to the version proposed by Ahmad and Stern (1984), we again assume a utilitarian social welfare function with no inequality aversion $(\varepsilon = 0)$.

Recall that the nominator of (20) is an approximate measure that is valid only for a marginal change in prices. Although, in theory, θ^h depends on prices, in the literature it is common to assume it is price-invariant for an infinitesimal price change. In other words, the nominator of (20) suggests that, if households do not change their demand, the welfare impact of a price change becomes proportional to expenditures on commodity i. Banks et al. (1996) compare such first-order approximations to simulated values from a quadratic demand system and demonstrate that the former are biased for non-marginal, but realistic degrees of tax changes.

Turning our attention to the denominator of (20), M_i denotes aggregate expenditures on commodity i

$$M_i = \sum_{h=1}^{H} m^h w_i^h. \tag{23}$$

Note that the partial effect of taxes on fiscal revenues is expressed in terms of the uncompensated cross-price elasticities of demand e^u_{ki}. Similar to the welfare effect, the latter expression is also an approximate measure assuming marginal changes in taxes. However, this approximation is likely to be biased for plausible degrees of tax changes, especially in the context of quadratic demand systems. More details on the derivation of MWG_i^{AS} can be found in Appendix A.

In what follows, we estimate the QUAIDS demand model using Slovak household-level consumption data. Cross-sectional variation in consumption and prices allow us to identify the parameters of the model's budget share equations in (8). Consequently, the fitted budget shares will also allow us to model the demand response of each household in the sample following price (or tax) changes. Finally, fitted household utility values and altered budget shares will facilitate the estimation of the fiscal (16) and welfare (17) impacts of price changes.

3. DATA

Our dataset comes from the Household Budget Survey (HBS) conducted by the Statistical Office of the Slovak Republic. The survey's main purpose is to collect information on sources of income and the allocation of household expenditures. The data also contain information on socio-demographic indicators, such as the gender, age, education, labor status, etc., of each household member. Households report the detailed structure of their consumption corresponding to a given month; however, only the quarter in which the questionnaire was filled in would be recorded in the database. Each of the annual representative samples consists of about 4500 to 6000 respondents. Unfortunately, a panel dataset cannot be formed because the sample is selected randomly each year. The observed time interval covers the years 2006 to 2012, which capture both the period of economic boom before 2008 and the stagnation after 2009.

For the purposes of this paper, we aggregated the detailed expenditure items observed in the data into nine bundles. These are (1) Bread, (2) Other cereals, (3) Unprocessed meat, (4) Processed meat, (5) Milk and butter, (6) Other dairy, (7) Fruits and vegetables, (8) Other foods, and (9) Other non-foods (see Table B.1 for a detailed list of items in each group). The division of items into the above categories was motivated mainly by the recent VAT cut in Slovakia. The tax change introduced a reduced VAT rate for bundles (1), (3), and (5), while the standard rate on some closely related alternatives, i.e., (2), (4), and (6), remained unchanged. With such a policy, the government aimed to focus the tax cut on basic, non-luxurious foods with the lowest possible share of imports, hereby supporting both low-income households and domestic producers. Apart from the above division, which is based on the coverage of the VAT cut, the structure of our aggregated consumption bundles is similar to those of prior studies on food demand (e.g., Moro and Sckokai, 2000; Abdulai, 2002; Cupák et al., 2015).[15]

Note that prices are not surveyed directly in the HBS; however, implicit prices can be computed for a subset of consumption by dividing expenditures and physical quantities purchased for each item, where the latter information is available only for foods. Consequently, we can form price indexes for the aggregated food bundles of the model as weighted geometric means; this can be done by using budget shares of the particular items as weights (see, e.g., Abdulai, 2002). However, by following this procedure, we also gain considerable variation in household-specific prices. The variation in prices typically stems from quality differences, regional market conditions, or seasonal effects (see Deaton, 1988). To adjust prices for the abovementioned effects, we follow the regression-based approach first proposed by Cox and Wohlgenant (1986).[16] Finally, we acquire the missing price information on the consumption of non-foods in the HBS from Eurostat's quarterly HICP indexes[17] in a commodity breakdown into 12 COICOP[18] categories. As in the case of foods, we use household-specific budget shares from the HBS to construct the weighted price variable for bundle (9).[19]

The definitions and summary statistics of the main variables entering the QUAIDS model are presented in Tables B.2 and B.3, respectively. As can be seen in B.3, the highest share of total household expenditure is allocated to non-food goods and services (around 75%). Among the food categories, households spend the most on unprocessed meat (5%) and the least on other cereal or milk products (2% each).[20] The increasing average prices of some bundles, i.e., other non-foods, were accompanied by increasing total household expenditure, from around €700 in 2006 to €800 in 2012. We also provide definitions of demographic variables and their summary statistics in Tables B.2 and B.3. The particular demographic indicators are chosen based on data availability and the existing literature on demand models.

[15]The only difference in terms of aggregation from the cited papers is that we split bundles (1) and (2), (3) and (4), and (5) and (6) according to the VAT cut.

[16]In this approach, deviations from regional quarterly mean prices of the i-th food bundle are regressed on household socio-economic characteristics such as income (and its quadratic term), family size (and its quadratic term), number of children, as well as age, education, and working status of the household head. Finally, the quality-adjusted prices of the i-th food bundle are computed by adding the residuals from the particular price deviation regression to the regional quarterly mean prices. The estimates of the abovementioned regressions are available from the authors upon request.

[17]Index values are equal to one for each commodity aggregate for the average of the base year 2005.

[18]The COICOP is the United Nations Classification of individual consumption by purpose, which is adapted by Eurostat to the compilation of the harmonized index of consumer prices (HICP) of the European Union and the euro area.

[19]The use of implicit prices from the HBS for foods and consumer price indexes in a commodity breakdown for non-foods follows the approach of Dybczak et al. (2014).

[20]It is worth mentioning that the Slovak households allocate around 16% of their total expenditure to food categories, whereas the European average is just about 11%.

4. Estimation

The estimation of a QUAIDS for nine consumption bundles is performed in Stata, using a set of commands recently developed by Lecocq and Robin (2015). While Banks et al. (1997) estimate the QUAIDS by a two-stage generalized method of moments (GMM) estimator. In comparison, Lecocq and Robin (2015) implement a computationally more attractive iterated linear least-squares estimator, originally proposed by Blundell and Robin (1999). A further estimator we can consider is the non-linear seemingly unrelated regressions (SUR), suggested by Poi (2002, 2008, 2012), although this estimator is computationally more demanding compared with others.

The presence of considerable cross-sectional heterogeneity in household-level data has led to the inclusion of socio-demographic effects in demand systems. The literature offers two alternative methods to implement them. The one we follow is the translating approach introduced by Pollak and Wales (1981), who propose shifting the intercept α_i in the budget share equations by a linear combination of demographic effects. In addition, the adjusted α_i-s enter the budget share equations via the price aggregator $a(p)$, which represents a non-linear effect. Another option is the scaling technique proposed by Ray (1983). By rescaling the data, the latter approach allows to reflect socio-demographic heterogeneity in both the level and slope coefficients of budget share equations.

When estimating demand models from detailed micro-data, researchers often face the problem of censoring, i.e., no recorded purchases of goods or services by households during the surveyed time period. Zero expenditures can arise from various reasons: the infrequency of purchase due to a short recording period of the survey, never purchasing particular goods or services, or unwillingness to purchase at given income level or prices, with the latter being a typical corner solution problem. Estimating a demand system from data containing frequent zero expenditures can lead to biased parameter estimates (e.g. Barslund, 2011), and to overcome this problem, different two-step estimation procedures have been proposed in the literature (e.g., Heien and Wesseils, 1990; Shonkwiler and Yen, 1999; Tauchmann, 2010). These procedures have been frequently applied in empirical work on demand systems (e.g., Yen et al., 2002; García-Enríquez and Echevarría, 2016; Savage, 2016). However, in our case, zero expenditures almost vanish after the aggregation of items into broader categories.[21] Therefore, in the current work, we ignore the censoring issue in our estimation of the demand system.

Table B.4 presents our demand system estimates. As can be seen, most of the estimated budget share equations are statistically significant with relatively high R^2 and p-values of the F-tests, which are both smaller than the conventional levels of significance. Likewise, the majority of the estimated parameters of the QUAIDS model are statistically significant, and the parameters capturing the quadratic expenditure term (λ's) as well as demographic variables are also highly statistically significant in most of the cases. These findings confirm the importance of flexible Engel curves and demographic effects in estimating household behavioral responses to changes in income and prices.

The sample average budget and price elasticities based on the estimated QUAIDS model are summarized in Table B.5. As can be seen, all elasticities are consistent with microeconomic theory and comparable to the results reported by other European studies (e.g., Moro and Sckokai, 2000; Abdulai, 2002). In addition, budget elasticities for all food bundles are smaller than 1, suggesting that foods are indeed necessities. The compensated own-price elasticities suggest that most of the goods in the model are price-inelastic. The only exceptions are processed

[21] The highest share of zero observations occurs in case of unprocessed meat (3.5%) and milk and butter (2%), while the same proportion drops below 0.6% for the remaining seven bundles.

meat, fruits, and vegetables and other non-foods, which are slightly more than unit-elastic with the respective compensated elasticities of -1.091 and -1.018. Meanwhile, some of the compensated cross-price elasticities are positive (negative), indicating that the particular pairs of bundles are substitutes (complements).

5. Simulating VAT cuts for foods

This section aims to evaluate the recent VAT cut in Slovakia from the efficiency perspective. Based on the new tax code, the standard rate of 20% is reduced to 10% for certain basic foods, namely, bread, unprocessed meat, milk and butter (all included in our model). First, we individually simulate the welfare and fiscal impacts of a tax cut for each bundle of the model (Subsection 5.1), while the ratio of the two impacts gives the efficiency indicator (i.e., MWG). In Subsection 5.2, we estimate the efficiency of tax cuts on multiple bundles, including a version mimicking the actual VAT cut in Slovakia and some other hypothetical alternatives. In the following two subsections, we check the sensitivity of our general results to equity considerations as well as the assumption of a 10% reduced rate. Subsection 5.5 compares the commonly used approximate measure of MWG proposed by Ahmad and Stern (1984) to our alternative, which is derived from the model simulations. Finally, Subsection 5.6 estimates the welfare impacts of hypothetical revenue-neutral VAT reforms.

Simulations are performed in the following steps. First, we estimate the demand system and then save the fitted budget shares for each bundle and household based on (8). We also estimate the initial values of indirect utility for each household according to (1), which is required for calculating the welfare impacts. Further, assuming a fully shifted 10 p.p. VAT cut to prices, we multiply the price observations of a particular bundle by $\tau = 1.1/1.2 \approx 0.927$ (i.e., a price cut by about 8.3%) in order to simulate a reduced rate. Then, we save the new fitted budget shares using the changed price data and the previously estimated parameters. In the final step, we compute the simulated household-specific changes in welfare and tax revenues labeled as ΔW_i and -ΔR_i, respectively. The ratio of these two expressions gives the MWG (19).

The above assumption of a fully shifted tax change to consumer prices is commonly found in the literature on commodity tax reforms. Authors in this field often assume constant returns to scale, fixed producer prices, the absence of pure profits, or a perfectly elastic supply, all of which lead to full tax shifting.[22] Accordingly, Madden (1995) argues that a perfectly elastic supply of tradable goods in a small open economy is a realistic assumption. This likely holds for food products in Slovakia too, especially when viewed from a long-run perspective. Complete pass-on of taxes to prices may not always materialize (Stern, 1987; Fullerton and Metcalf, 2002), especially within imperfectly competitive markets.[23] Yet, a further issue may arise from a potentially asymmetric pass-through, that is, a more limited price response to VAT cuts than to tax hikes.[24] In summary, we assume that a particular degree of pass-through is an empirical issue, which can only be addressed based on product- and market-specific evidence.

As regards pass-through estimates that are relevant to our paper, those presented by Benedek et al. (2015) are one of the few available in the literature. The authors use monthly consumer

[22] See e.g., Ahmad and Stern (1984), Banks et al. (1996, 1997), Decoster and Schokkaert (1989, 1990), Decoster et al. (2010), García-Enríquez and Echevarría (2016), Madden (1995, 1996) Santoro (2007) and Savage (2016).

[23] See also Delipalla and Keen (1992), Poterba (1996), and Besley and Rosen (1999).

[24] Such asymmetry can follow from increasing marginal inventory costs (Blinder, 1982), lower consumer search costs if prices are falling (Benabou and Gertner, 1993; Lewis, 2011), or simply from market concentration (Carlton, 1986; Deltas, 2008; Verlinda, 2008).

price data, which are disaggregated by detailed commodity groups in 17 eurozone countries (including Slovakia), in order to estimate the pass-through of all VAT changes legislated during 1999-2013. They cannot reject the hypothesis of a complete pass-through in case of changes in standard VAT rates, but they find a lower pass-through (around 30%) for changes in reduced rates. Benedek et al. (2015) also cannot reject the symmetric incidence of VAT cuts and hikes to prices. At the same time, estimates from other studies typically come from a single country and may be related to rather specific commodities. This may be the reason explaining the highly heterogenous results.[25]

5.1 VAT CUTS FOR INDIVIDUAL BUNDLES

Demand responses to 8.3%[26] price cuts for individual bundles can be characterized by a minor adjustment in budget shares. In terms of percentage changes, however, we find a notable decrease in nominal expenditures and a less than 8.3% increase in real expenditures for most bundles, thus reflecting a price-inelastic demand. In contrast, a slightly price-elastic response is recorded in the three bundles, including fruits and vegetables, processed meat, and other non-foods. The above findings are in accordance with the estimated uncompensated own-price elasticities shown in Table B.5. The sample average demand responses for each bundle are summarized in Table B.6 in Appendix B.

Next, let us turn our attention to the welfare and fiscal impacts, which are the two components of the efficiency indicator (i.e., MWG). As can be seen, columns 3 and 4 in Table 1 present the changes in welfare, which are expressed in monetary terms and also as a proportion of total expenditures.[27] The additional indicators in the first two columns help explain the welfare ranking of bundles according to column 4. Other things equal, one may expect that a larger demand response to a bundle's own VAT cut (column 1) may indicate a larger increase in welfare (column 4). However, this rule of thumb does not always predict the ranking correctly, in particular for rows 1 versus 2, 4 versus 8, and 7 versus 8.

Table 1: Marginal welfare gains of a VAT cut from 20% to 10%

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Change in real exp. on bundle i	Average change in real exp. on other bundles	Compensating variation		Fiscal cost per household		Marginal welfare gain
VAT cut for bundle i:	$mw_i/\tau p_i$ (%)	mw_{-i}/p_{-i} (%)	ΔW (EUR/month)	$\Delta W/m$ (%)	$-\Delta R$ (EUR/month)	$-\Delta R/m$ (%)	$-\Delta W/\Delta R$
1 Bread	4.07	-0.86	1.24	0.18	1.75	0.26	0.69
2 Other cereals	3.85	0.67	1.57	0.23	1.02	0.15	1.56
3 Unprocessed meat	1.58	-0.48	1.09	0.17	2.46	0.36	0.42
4 Processed meat	10.61	0.10	3.21	0.46	1.91	0.28	1.68
5 Milk and butter	6.36	-0.10	1.09	0.16	0.91	0.13	1.17
6 Other dairy	7.00	-0.29	1.28	0.19	1.88	0.27	0.69
7 Fruits and vegetables	9.74	-0.18	2.46	0.35	2.10	0.30	1.17
8 Other foods	7.93	0.68	3.60	0.52	2.35	0.34	1.54
9 Other non-foods	9.32	-0.70	47.15	6.20	47.31	6.21	1.00

Note: Sample means.
Source: Household Budget Survey, Slovak Statistical Office

[25] Full- or over-shifting is found for clothing prices in the U.S. by Poterba (1996) and for grocery products by Besley and Rosen (1999) and Meyler (2014) in the U.S. and the eurozone respectively. Evidence of undershifting is documented for retail services by Carbonnier (2007) in France and Kosonen (2015) in Finland, whereas Politi and Mattos (2011) reach a similar conclusion for food products in Brazil.

[26] Equivalent to a fully shifted 10 p.p. VAT cut, i.e., prices are multiplied by $\tau = 1.1/1.2 \approx 0.927$.

[27] Following the definition of ΔW in (17), the ratio $\Delta W/m$ is equal to the percentage change in welfare $\Delta W/W$.

The arithmetic average growth of real expenditures on the remaining bundles (column 2) can further explain the seemingly inconsistent ranking shown above. A positive (negative) average demand response suggests that complements (substitutes) prevail in the rest of the consumption basket. In other words, a higher average real growth of other bundles implies that, apart from the tax-subsidized bundle itself, households can also enjoy increased consumption of a greater variety of goods.[28] Based on the simulation results, it is evident that our welfare measure, which is derived from the utility function, reflects the effect of net complements or substitutes in the welfare ranking.

The next two columns, 5 and 6, describe the fiscal costs of each simulated tax cut, expressed in monetary terms (column 5) and as a share of total expenditures (column 6). As regards the former, the costs of the simulated tax changes are quite small, reaching an average of around 1 or 2 EUR per household per month. In contrast, from the fiscal point of view, a tax cut on the largest bundle of non-foods also appears to be the costliest. This amounts to about 47 EUR of the monthly budget of an average household.

The last column shows the MWGs, which indicate the efficiency of a simulated VAT cut for each bundle. In this regard, most food items dominate the largest composite good of Other non-foods, which is chosen as the reference category. Meanwhile, the highest MWG is associated with Processed meat (1.68); this can be explained by its outstanding own real expenditure response (column 1) and a slight prevalence of complements in the remainder of the basket (column 2). In contrast, Fruits and vegetables only have a somewhat smaller own real expenditure response, but a majority of substitutes among other goods; thus, their MWG is slightly lower (1.17), yet still above the reference value of unity. The food bundle with the third highest own real response, Other foods, is found to be strongly complementary relative to most other goods; thus, their resulting MWG (1.54) ranks as the third highest. Note that the above three bundles have a similar average budget share, which makes them comparable in terms of their fiscal revenue impacts (column 6).

Next, we can see that Other cereals have the second highest MWG (1.56) out of all the bundles; this result is observed despite its inelastic demand response. However, the bundle is, on average, complementary to the rest of the goods and has a relatively small budget share. The latter factor makes Other cereals efficient in terms of fiscal costs (column 6), indicating a small denominator of the MWG ratio. The only remaining bundle with an MWG above unity is Milk and butter (1.17), which also has a below-average budget share and, therefore, a low fiscal cost. An additional factor contributing positively to the MWG of this bundle is its relatively high demand response (6.4%), yet still in the inelastic range of below 8.3%. Moreover, most of the goods other than Milk and butter are their substitutes, which ceteris paribus decreases the efficiency of a tax cut.

The MWG of the remaining food bundles, such as Bread, Unprocessed meat, and Other dairy, fall below the reference value of 1. This result is driven by several factors: all three food bundles are substitutes to most of the consumption basket, have a price-inelastic demand response, and have just an average fiscal impact.

[28] For a detailed picture of how the real consumption of each bundle changes in particular simulations, see Figures 1 and 2.

5.2 VAT cuts for multiple bundles

Simulations from the previous subsection are now repeated for several combinations of bundles, including the one mimicking the actual VAT cut in Slovakia. As regards the efficiency of the actual VAT cut (0.62), it fails to reach the reference value of 1 (see Table 2). This is mainly due to two components associated with a low MWG: (1) Bread and (3) Unprocessed meat. The only component that slightly exceeds Other non-foods in terms of MWG is (5) Milk and butter. In addition, joining the three bundles in a single VAT cut simulation also worsened efficiency because of the dominance of substitutes among the other goods left out (column 2).

Table 2: Marginal welfare gains of a VAT cut from 20% to 10%

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Change in real exp. on bundle i	Average change in real exp. on other bundles	Compensating variation		Fiscal cost per household		Marginal welfare gain
VAT cut for bundle i:	$mw_i/\tau p_i$ (%)	mw_{-i}/p_{-i} (%)	ΔW (EUR/month)	$\Delta W/m$ (%)	$-\Delta R$ (EUR/month)	$-\Delta R/m$ (%)	$-\Delta W/\Delta R$
1, 3, 5 - the 2016 VAT cut	3.80	-1.86	3.43	0.51	5.12	0.75	0.62
2, 4, 5, 7, 8	5.35	1.77	11.89	1.70	8.31	1.01	1.43
2, 5, 7	7.32	0.38	5.12	0.74	4.04	0.58	1.27
1 - 8	5.65	0.87	15.43	2.23	14.31	2.08	1.08

Note: sample means.
Key: 1 - Bread, 2 - Other cereals, 3 - Unprocessed meat, 4 - Processed meat, 5 - Milk and butter, 6 - Other dairy, 7 - Fruits and vegetables, 8 - Other foods, 9 - Other non-foods.
Source: Household Budget Survey, Slovak Statistical Office

For comparison, we study three additional combinations of food bundles the government could have considered for a VAT cut. The first is based on our cherry-picking from goods with the highest MWGs, such as (4) Processed meat, (2) Other cereals, (8) Other foods, (5) Milk and butter, and (7) Fruits and vegetables. Of course, this implies the exclusion of two food bundles with the lowest MWGs, namely (1) Bread and (6) Other dairy. The second combination we selected on an ad hoc basis also excluded (4) Processed meat and (8) Other foods from the VAT cut. This is because the latter two are regarded as unhealthy. Specifically, processed meats tend to contain chemical preservatives and sodium, whereas other foods largely consist of fats and sweets. Thus, we could argue in favor of the second combination that a government while acting responsibly should not subsidize unhealthy foods. The third alternative VAT change we study is a cut for all food items. Arguably, this option is more advantageous compared with others in terms of administrative and implementation costs. Specifically, this means that public authorities would not have to differentiate between food items that are taxed at the reduced rate and those that are taxed at the standard rate. However, as its main disadvantage, the full set of foods contains elements that increase and decrease efficiency. As we can infer from Table 2, all the three hypothetical alternatives prevail over the actual VAT change in terms of efficiency.

5.3 Sensitivity check - marginal welfare gains by expenditure deciles

Apart from efficiency, another relevant economic question relates to the distributional impact of VAT reforms. This means exploring whether welfare and fiscal impacts are different across expenditure deciles. As shown in Figures 3 and 4, both the welfare and fiscal impacts are increasing in total expenditures (income) for all bundles (subfigures in the left column). However, both impacts are slightly decreasing (subfigures in the right column) if expressed as a percentage of total expenditures, and this tendency is related to the fact that food items are necessities and their budget shares are shrinking in higher expenditures or incomes. In contrast, for the non-food bundle, welfare and fiscal impacts expressed as shares of total expenditures are rising for higher deciles. The latter can be explained by the fact that the non-food aggregate is behaving as a luxury good.

Despite the increasing welfare and fiscal impacts for higher deciles, the ratio of the two remains roughly constant for all bundles (Figure 5). In other words, MWGs and their relative rankings across bundles are stable from the bottom to the top expenditure deciles, indicating that, equity considerations, assigning different social weights to households with varying expenditure level is not likely to change the efficiency rankings of the bundles.

5.4 Sensitivity check - marginal welfare gains by tax rates

Throughout our empirical analysis, we assume a fixed VAT cut from the base rate of 20% to a reduced rate of 10%. This is motivated by the case of the actual VAT cut in Slovakia. Given that the QUAIDS model is non-linear, one may ask whether our results are robust when using different reduced rates. Hence, we compute the median MWG for each bundle for a range of alternative tax rates. In particular, our simulations cover VATs ranging from 0% to 27%, by steps of 0.5 p.p.[29] This means that both tax cuts and hikes are considered for an individual bundle. Meanwhile, the upper bound of the range, 27%, is the highest currently observable VAT rate in the EU.

The MWGs for different tax rates are depicted in Figure 6. The results suggest that the efficiency rankings of bundles are quite stable for the range of tax rates considered. First, all MWG curves are linear and are slightly, but monotonically, decreasing in tax rates, suggesting that the closer the reduced rates are to zero, the more efficient the tax cut is. As a further implication, tax cuts are somewhat more efficient compared with tax hikes. Next, only some of the lines cross their adjacent ones, suggesting that the efficiency ranking can change slightly, but only for some pairs of bundles. These pairs are: (2) Other cereals and (8) Other foods, (5) Milk and butter and (7) Fruits and vegetables, and (1) Bread and (6) Other dairy.[30] Finally, the components of MWG, namely, changes in welfare and fiscal revenues by tax rates, are reported in Figures 7 and 8, respectively. As can be seen, the two indicators (i.e., changes in welfare and fiscal revenues) are linearly decreasing in the tax rate and are symmetric around the base rate of 20%.

5.5 An approximate measure of marginal welfare gains

As a benchmark, we also compute the approximate measure of MWG in (20) following Ahmad and Stern (1984), henceforth referred to as AS. We assume zero inequality aversion ($\varepsilon = 0$) and use budget shares fitted from the demand system. Table 3 below compares the MWG ratios, welfare impacts, and fiscal costs according to AS and our approach based on the simulated values from QUAIDS. In case of the welfare impact and the fiscal cost, we take the marginal effects shown in (20) and multiply them by the tax change (∂t = 0.1). All figures in Table 3 are based on the sample means.[31]

[29] Note that the base rate of 20% is excluded, where MWG is not defined.

[30] Tax changes for the first bundle in each pair are more efficient for lower rates and become somewhat less efficient for higher rates compared with the second bundle of the pair.

[31] For Ahmad and Stern (1984)'s MWG indicator by expenditure deciles, see Figures 9 and 10.

Table 3: Marginal welfare gains of a VAT cut from 20% to 10% - approximate vs. simulated values

VAT cut for bundle i:	(1)	(2)	(3)	(4)	(5)	(6)
	Welfare impact		Fiscal cost		Marginal welfare gain	
	AS (EUR/month)	QUAIDS (EUR/month)	AS (EUR/month)	QUAIDS (EUR/month)	AS (rank)	QUAIDS (rank)
1 Bread	1.83	1.24	1.85	1.75	2	8
2 Other cereals	1.07	1.57	1.09	1.02	6	2
3 Unprocessed meat	2.64	1.09	2.69	2.46	7	9
4 Processed meat	1.89	3.21	1.93	1.91	8	1
5 Milk and butter	0.93	1.09	0.95	0.91	9	5
6 Other dairy	1.92	1.28	1.94	1.88	4	7
7 Fruits and vegetables	2.09	2.46	2.12	2.10	5	4
8 Other foods	2.38	3.60	2.41	2.35	3	3
9 Other non-foods	47.20	47.15	47.11	47.31	1	6
1, 3, 5 - the 2016 VAT cut	5.40	3.43	5.49	5.12	2	4
2, 4, 5, 7, 8	8.36	11.89	8.50	8.31	3	1
2, 5, 7	4.09	5.12	4.16	4.04	4	2
1 - 8	14.98	14.31	14.74	15.43	1	3

Note: sample means.
Source: Household Budget Survey, Slovak Statistical Office

As expected from prior studies (e.g., Banks et al., 1996), the approximate welfare impacts are biased when compared with the simulated results, although by looking at the first two columns of Table 3, we can see that the AS estimate does not deviate systematically upwards or downwards. These results suggest that the direction of bias depends on the commodity bundle considered. In contrast, the fiscal cost estimates of AS and those from QUAIDS simulations do not differ much. However, the former measure tends to slightly overestimate the fiscal cost for food items and underestimate it for the non-food bundle.

Finally, considering the MWG ratio, the indicators based on AS and QUAIDS produce completely different rankings of the bundles,[32] as shown by the last two columns of Table 3. The main reason for disagreement is probably the numerator, that is, the estimate of the welfare impact. This is due to the fact that the bias of the approximate welfare impact can be both positive and negative, and is relatively larger in absolute value compared with the bias in the approximate fiscal impact. A secondary cause of differences in the alternative rankings is the small upward bias in the estimated fiscal costs for foods and the slight downward bias for non-foods, with the latter contributing to the highest rank of non-foods based on the AS approach.

5.6 Welfare gains from revenue-neutral reforms

With the aim of identifying potential revenue-neutral welfare-improving VAT reforms, we compare the efficiency of tax cuts on various food bundles vis-à-vis the reference category, namely, Other non-foods, when describing the simulation results above. Such reforms cut the VAT on goods associated with a high welfare gain while simultaneously increasing the VAT on goods with a low welfare gain. At the same time, the fiscal impact is kept zero. In our setup, a minor VAT hike on the large bundle of Other non-foods can provide sufficient fiscal revenues to finance significant tax cuts on any of the food bundles. Therefore this subsection is devoted to simulating cuts on different food items combined with hikes on non-food ones.

[32] A statistically significant difference between the two rankings is confirmed by Kendall's non-parametric rank correlation test. A p-value of 0.466 for Kendall's τ statistic suggests that the null hypothesis of independence of the two rankings cannot be rejected.

We introduce exogenous price changes in the model when simulating revenue-neutral tax reforms. The changes reflect a reduced rate of 10% for one or more food bundles and an increased rate for the non-food bundle. As for the remainder of the food basket, the standard rate of 20% is preserved. We used grid search with gradual 0.01 p.p. increases in VAT to find the increased rate on non-food, which would minimize the fiscal impact (ΔR). Once the revenue-neutral tax scheme is identified, we use the model to estimate the compensating variation, that is, the welfare impact.

Results of the above exercise are presented in Table 4. The rows list the eight food bundles and their four combinations, to which a reduced rate of 10% is applied. The first column reports the increased VAT rates for Other non-foods, which makes the hypothetical tax change revenue-neutral. The second column displays the sample average welfare impacts expressed in euro per month and household. The third and fourth columns of the table compare the rankings of policies in terms of the welfare impact in column 2 and their efficiency indicators (MWG), respectively. The latter ranking is copied from the last column of Table 3 in the previous subsection, however, bundle (9), Other non-foods, is not ranked in this case.

Table 4: Welfare gains from revenue-neutral VAT cuts from 20% to 10%

	(1)	(2)	(3)	(4)
	VAT rate on non-food	Revenue-neutral welfare impact		MWG by QUAIDS
VAT cut to 10% for bundles:		(EUR/month)	(rank)	(rank)
1 Bread	20.37%	-0.49	6	7
2 Other cereals	20.22%	0.55	3	2
3 Unprocessed meat	20.52%	-1.34	8	8
4 Processed meat	20.40%	1.35	2	1
5 Milk and butter	20.17%	0.30	5	5
6 Other dairy	20.40%	-0.59	7	6
7 Fruits and vegetables	20.43%	0.46	4	4
8 Other foods	20.48%	1.37	1	3
1, 3, 5 - the 2016 VAT cut	21.06%	-1.54	4	4
2, 4, 5, 7, 8	21.73%	3.94	1	1
2, 5, 7	20.84%	1.22	3	2
1 - 8	23.00%	1.62	2	3

Note: sample means.
Source: Household Budget Survey, Slovak Statistical Office

Our findings suggest that the revenue-neutral welfare effects are mostly positive, but rather small. Three cases of negative impacts are observed: (1) Bread, (3) Unprocessed meat, and (6) Other dairy. This means that we cannot find revenue-neutral welfare-improving tax schemes for these bundles. This can be attributed to the fact that the mentioned foods have a lower MWG than Other non-foods, which is the financing bundle. The same finding holds for the actual Slovak VAT cut, which combined foods 1, 3, and 5 (i.e., two with the lowest MWG). Overall, we can conclude that the efficiency indicators estimated in the previous subsections are useful, as they well predict the list of food bundles that allow for revenue-neutral welfare improvements.

In addition, comparing the rankings in columns 3 and 4, we find that they are broadly similar.[33] However, some disagreement up to one rank can be observed for some bundles. This outcome

[33]The rankings are not found to be statistically different. The p-value of Kendall's τ statistic (0.009) suggests the rejection of the null of independence.

may have been produced by the interplay between the welfare gain from a reduced rate and the welfare loss from an increased rate, in case of a revenue-neutral simulation. Overall, the above results suggest that the MWG indicators are relatively good predictors of the ordering of revenue-neutral schemes. However, we must estimate the revenue-neutral welfare impacts to determine the exact ordering.

Next, we consider a zero rate, instead of a 10% rate on food, in order to test the robustness of the results above. However, the welfare ranking of revenue-neutral policies was not sensitive to this assumption. The results for a zero rate can be found in Table B.8 in Appendix B. As shown in the table, the estimated welfare impacts in the latter case are slightly more than twice the original values shown in Table 4. Furthermore, the required percentage point increases of the tax rates on non-foods are also approximately twice the VAT hikes shown in Table 4.

Furthermore, we look at the revenue-neutral welfare impacts as a function of the reduced rate, to verify whether non-linearities occur in this relationship. Here, we consider a range of reduced rates from 0% to 19% by steps of one percentage point. As we can see from Figures 11 and 12, the welfare impact is a roughly linear function of the reduced rate for each food bundle and their combinations, respectively. At the same time, the lines do not cross each-other, suggesting that the ranking is stable over the realistic range of reduced rates.

In contrast, the welfare ranking of the discussed policies may be somewhat sensitive to equity considerations. This means that some of the welfare curves plotted against expenditure deciles may cross one another (see Figures 13 and 14), implying changes in the rankings for some deciles. However, we only find this sensitivity for combined food bundles, and not for the eight single foods. The latter finding may be related to the fact that reducing VAT for more bundles requires an excessively large tax hike on non-foods. Specifically, given that foods are necessities and non-foods behave as luxuries, the welfare costs of the revenue-neutral reform may dominate the welfare benefits beyond some threshold level of the total expenditures.

6. Conclusion

We estimated a Quadratic Almost Ideal Demand System for eight food bundles and a non-food aggregate using Slovak household-level data. Using the model, we simulated household-level demand responses to the recent Slovak VAT cut and its other hypothetical alternatives. The model enabled us to quantify the impacts of such a VAT cut on household welfare and fiscal revenues. We used the ratio of the welfare and fiscal effects as an efficiency indicator, which we referred to as the marginal welfare gain. This allowed us to rank the commodity bundles of the model, or their combinations. According to our results, the efficiency of a tax cut is higher if demand for a good is price-elastic or if the good has several complements in the consumption basket. Hence, we find that cherry-picking from food sub-categories could help improve the efficiency of the Slovak VAT cut.

The paper contributes to the literature in two aspects. First, we used simulation results, instead of the standard approximate measures, in constructing the efficiency indicator of tax reforms. We showed that the latter approach, which is commonly used in the literature, leads to a biased ranking of the alternative policies. The bias results mainly from the fact that the approximate welfare impact ignores demand responses, e.g. by not taking into account substitution effects. Meanwhile, the bias of the fiscal impact stems from the imprecision of price elasticities as predictors of demand responses compared to simulations. This imprecision may be aggravated, especially in the case of a non-linear model and non-incremental changes in prices or taxes.

Second, the analysis of MWGs from tax reforms relates to theories on the optimal structure of indirect taxes and the literature on marginal tax reforms. We contribute to those fields with new evidence of hypothetical reforms that can help increase the welfare of households at zero fiscal costs in Slovakia. The tax changes we examined departed from a homogenous VAT scheme by introducing a reduced rate on foods and an increased rate on non-foods. We found that the examined tax changes can improve welfare in case of the majority of food items. Welfare improvements are confirmed even for a reduced rate on all foods financed by an increased rate on non-foods. However, potential welfare gains are rather small in Slovakia, reaching only about 1.5% of total expenditures (about 9 EUR per household and month) if a zero rate is assumed for selected foods.

As regards the general policy implications of our results, we conclude that countries aiming to design efficient VAT reforms can use a demand model to rank commodities according to their MWGs. In particular, such a ranking can provide guidance for cherry-picking among closely related products that are considered in an indirect tax reform. In addition, the ranking can also provide guidance for identifying potential revenue-neutral welfare-improving tax reforms. However, we recommend relying on the simulation results to estimate the welfare and fiscal impacts of reform alternatives, rather than following the approximate measures of the impacts.

References

Abdulai, A. (2002). Household Demand for Food in Switzerland. A Quadratic Almost Ideal Demand System. *Swiss Journal of Economics and Statistics 138*(I), 1–18.

Ahmad, E. and N. Stern (1984). The Theory of Reform and Indian Indirect Taxes. *Journal of Public Economics 25*(3), 259–298.

Atkinson, A. B. and J. E. Stiglitz (1976). The Design of Tax Structure: Direct Versus Indirect Taxation. *Journal of Public Economics 6*(1-2), 55–75.

Atkinson, A. B. and J. E. Stiglitz (1980). *Lectures on Public Economics*. London: McGraw Hill.

Banks, J., R. Blundell, and A. Lewbel (1996). Tax Reform and Welfare Measurement: Do We Need Demand System Estimation? *The Economic Journal 106*(438), 1227–41.

Banks, J., R. Blundell, and A. Lewbel (1997). Quadratic Engel Curves and Consumer Demand. *The Review of Economics and Statistics 79*(4), 527–539.

Barslund, M. (2011). Censored Demand System Estimation with Endogenous Expenditures in Clustered Samples: An Application to Food Demand in Urban Mozambique. Technical report, LICOS-Centre for Institutions and Economic Performance, KU Leuven.

Barten, A. P. (1964). Consumer Demand Functions Under Conditions of Almost Additive Preferences. *Econometrica 32*(1/2), 1–38.

Benabou, R. and R. Gertner (1993). Search with learning from prices: does increased inflationary uncertainty lead to higher markups? *The Review of Economic Studies 60*(1), 69–93.

Benedek, D., R. de Mooij, and P. Wingender (2015). Estimating VAT pass through. IMF Working Paper 15/214, International Monetary Fund, Washington DC, USA.

Besley, T. J. and H. S. Rosen (1999). Sales taxes and prices: an empirical analysis. *National Tax Journal 52*(2), 157–158.

Blinder, A. S. (1982). Inventories and sticky prices: More on the microfoundations of macroeconomics. *American Economic Review 72*(3), 334–348.

Blundell, R. and J.-M. Robin (1999). Estimation in Large and Disaggregated Demand Systems: An Estimator for Conditionally Linear Systems. *Journal of Applied Econometrics 14*(3), 209–329.

Bosch, L. H. M. and P. J. van den Noord (1990). Alternative Financing of Social Insurance Systems. *Journal of Policy Modeling 12*(1), 61–76.

Carbonnier, C. (2007). Who pays sales taxes? evidence from french VAT reforms, 1987–1999. *Journal of Public Economics 91*(5), 1219–1229.

Carlton, D. W. (1986). The rigidity of prices. *American Economic Review 76*(4), 637–658.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1975). Transcendental Logarithmic Utility Functions. *American Economic Review 65*(3), 367–383.

Cox, T. L. and M. K. Wohlgenant (1986). Prices and Quality Effects in Cross-sectional Demand Analysis. *American Journal of Agricultural Economics 68*(4), 908–919.

Cragg, M. (1991). Do We Care? A Study of Canada's Indirect Taxation. *Canadian Journal of Economics 24*(1), 124–143.

Crawford, I., M. Keen, and S. Smith (2010). Value-Added Tax and Excises. In S. Adam, T. Besley, R. Blundell, S. Bond, R. Chote, M. Gammie, P. Johnson, G. Myles, and J. M. Poterba (Eds.), *Dimensions of Tax Design*, Chapter 4, pp. 275–422. Oxford: Oxford University Press.

Cupák, A., J. Pokrivčák, and M. Rizov (2015). Food demand and consumption patterns in the new EU member states: the case of Slovakia. *Journal of Economics (Ekonomický časopis) 63*(4), 339–358.

Deaton, A. (1988). Quality, Quantity, and Spatial Variation of Price. *American Economic Review 78*(3), 418–430.

Deaton, A. and J. Muellbauer (1980). An Almost Ideal Demand System. *American Economic Review 70*(3), 312–326.

Decoster, A., J. Loughrey, C. O'Donoghue, and D. Verwerft (2010). How Regressive Are Indirect Taxes? A Microsimulation Analysis for Five European Countries. *Journal of Policy Analysis and Management 29*(2), 326–350.

Decoster, A. and E. Schokkaert (1989). Equity and Efficiency of a Reform of Belgian Indirect Taxes. *Recherches Economiques de Louvain / Louvain Economic Review 55*(2), 155–176.

Decoster, A. and E. Schokkaert (1990). Tax Reform Results with Different Demand Systems. *Journal of Public Economics 41*(3), 277–296.

Delipalla, S. and M. Keen (1992). The comparison between ad valorem and specific taxation under imperfect competition. *Journal of Public Economics 49*(3), 351–367.

Deltas, G. (2008). Retail gasoline price dynamics and local market power. *The Journal of Industrial Economics 56*(3), 613–628.

Diamond, P. and J. Mirrlees (1971a). Optimal Taxation and Public Production I: Production Efficiency. *American Economic Review 61*(1), 8–27.

Diamond, P. and J. Mirrlees (1971b). Optimal Taxation and Public Production II: Tax Rules. *American Economic Review 61*(3), 261–278.

Dybczak, K., P. Tóth, and D. Voňka (2014). Effects of price shocks on consumer demand: Estimating the QUAIDS demand system on Czech household budget survey data. *Czech Journal of Economics and Finance (Finance a úvěr) 64*(6), 476–500.

Fullerton, D. and G. E. Metcalf (2002). Tax incidence. In A. Auerbach and M. Feldstein (Eds.), *Handbook of Public Economics*, Volume 4, Chapter 26, pp. 1787–1872. Amsterdam: Elsevier.

García-Enríquez, J. and C. A. Echevarría (2016). Consistent Estimation of a Censored Demand System and Welfare Analysis: The 2012 VAT Reform in Spain. *Journal of Agricultural Economics 67*(2), 324–347.

Heien, D. and C. R. Wesseils (1990). Demand Systems Estimation with Microdata: A Censored Regression Approach. *Journal of Business and Economic Statistics 8*(3), 365–371.

Hicks, J. R. (1939). The Foundations of Welfare Economics. *The Economic Journal 49*(196), 696–712.

Janský, P. (2014). Consumer Demand System Estimation and Value Added Tax Reforms in the Czech Republic. *Czech Journal of Economics and Finance (Finance a úvěr) 64*(3), 246–273.

Kaiser, H. and B. P. Spahn (1989). On the Efficiency and Distributive Justice of Consumption Taxes: A Study on VAT in West Germany. *Zeitschrift für Nationalökonomie / Journal of Economics 49*(2), 199–218.

Kaplanoglou, G. and D. M. Newbery (2003). Indirect Taxation in Greece: Evaluation and Possible Reform. *International Tax and Public Finance 10*(5), 511–533.

Kosonen, T. (2015). More and cheaper haircuts after VAT cut? on the efficiency and incidence of service sector consumption taxes. *Journal of Public Economics 131*(C), 87–100.

Lecocq, S. and J.-M. Robin (2015). Estimating Almost-Ideal Demand Systems with Endogenous Regressors. *Stata Journal 15*(2), 554–573.

Lewis, M. S. (2011). Asymmetric price adjustment and consumer search: an examination of the retail gasoline market. *Journal of Economics and Management Strategy 20*(2), 409–449.

Madden, D. (1995). An Analysis of Indirect Tax Reform in Ireland in the 1980s. *Fiscal Studies 16*(2), 18–37.

Madden, D. (1996). Marginal Tax Reform and the Specification of Consumer Demand Systems. *Oxford Economic Papers 48*(4), 556–567.

Meyler, A. (2014). VAT pass-through: Is there any value-added in a disaggregated cross-country and cross-product analysis? Mimeo. A summary is published in ECB Economic Bulletin 2015, Issue 1, p. 45-47.

Moro, D. and P. Sckokai (2000). Heterogeneous Preferences in Household Food Consumption in Italy. *European Review of Agricultural Economics 27*(3), 305–323.

Poi, B. P. (2002). From the Help Desk: Demand System Estimation. *Stata Journal 2*(4), 403–410.

Poi, B. P. (2008). Demand-system Estimation: Update. *Stata Journal 8*(4), 554–556.

Poi, B. P. (2012). Easy Demand-system Estimation with quaids. *Stata Journal 12*(3), 433–446.

Politi, R. B. and E. Mattos (2011). Ad-valorem tax incidence and after-tax price adjustments: evidence from brazilian basic basket food. *Canadian Journal of Economics/Revue canadienne d'économique 44*(4), 1438–1470.

Pollak, R. A. and T. J. Wales (1981). Demographic Variables in Demand Analysis. *Econometrica 49*(6), 1533–51.

Poterba, J. M. (1996). Retail price reactions to changes in state and local sales taxes. *National Tax Journal 49*(2), 165–176.

Ramsey, F. P. (1927). A Contribution to the Theory of Taxation. *The Economic Journal 37*(145), 47–61.

Ray, R. (1983). Measuring the Costs of Children: An Alternative Approach. *Journal of Public Economics 22*(1), 89–102.

Santoro, A. (2007). Marginal Commodity Tax Reforms: A Survey. *Journal of Economic Surveys 21*(4), 827–848.

Savage, M. (2016). Indirect Tax Teform and the Specification of Demand: The Case of Ireland. *International Tax and Public Finance 23*(2), 368–399.

Shonkwiler, J. S. and S. T. Yen (1999). Two-step Estimation of a Censored System of Equations. *American Journal of Agricultural Economics 81*(4), 972–982.

Stern, N. (1987). Aspects of the general theory of tax reform. In D. Newbery and N. Stern (Eds.), *The Theory of Taxation for Developing Countries*, Chapter 3, pp. 60–91. Oxford: World Bank and Oxford University Press.

Stone, R. (1954). Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand. *The Economic Journal 64*(255), 511–527.

Tauchmann, H. (2010). Consistency of Heckman-type Two-step Estimators for the Multivariate Sample-selection Model. *Applied Economics 42*(30), 3895–3902.

Urakawa, K. and T. Oshio (2010). Comparing Marginal Commodity Tax Reforms in Japan and Korea. *Journal of Asian Economics 21*(6), 579–592.

Urzúa, C. M. (2005). The Ahmad-Stern Approach Revisited. *Economics Bulletin 8*(4), 1–8.

Verlinda, J. A. (2008). Do rockets rise faster and feathers fall slower in an atmosphere of local market power? evidence from the retail gasoline market. *The Journal of Industrial Economics 56*(3), 581–612.

Yen, S. T., K. Kan, and S.-J. Su (2002). Household Demand for Fats and Oils: Two-step Estimation of a Censored Demand System. *Applied Economics 34*(14), 1799–1806.

APPENDIX

A. MARGINAL WELFARE GAINS BY AHMAD AND STERN (1984)

In what follows, we derive Marginal Welfare Gains (MWGs) according to Ahmad and Stern (1984). Consistently with (14), we assume a proportional[34] VAT rate t, which links consumer prices p and producer prices p^0 as: $p = p^0(1+t)$.

The social welfare function U is of the Bergson-Samuelson type, which is defined over the indirect utility functions V^h of households $h = 1, ..., H$ shown below.

$$U = U\left[V^1(m^1, p), ..., V^H(m^H, p)\right] \tag{A.1}$$

The social marginal utility of income of household h, which is the household's weight in social welfare, is expressed as

$$\theta^h = \frac{\partial U\left[V^1(m^1, p), ..., V^H(m^H, p)\right]}{\partial V^h\left(m^h, p\right)} \frac{\partial V^h\left(m^h, p\right)}{\partial m^h}. \tag{A.2}$$

For an infinitesimal change in price p_i, the change in social welfare can be approximated by the first derivative of U with respect to p_i using the equation below.

$$\frac{\Delta U}{\Delta p_i} = \frac{U(p_i + \Delta p_i)}{\Delta p_i} \approx \frac{\partial U}{\partial p_i} \tag{A.3}$$

Using the definition of θ^h and Roy's identity, we can rewrite (A.3) as follows.

$$\frac{\partial U}{\partial p_i} = \sum_{h=1}^{H} \frac{\partial U\left[V^1(m^1, p), ..., V^H(m^H, p)\right]}{\partial V^h\left(m^h, p\right)} \frac{\partial V^h\left(m^h, p\right)}{\partial p} = -\sum_{h=1}^{H} \theta^h \frac{m^h w_i^h}{p_i} \tag{A.4}$$

Finally, considering a marginal change in the proportional tax rate, the first derivative of U with respect to t_i becomes

$$\frac{\partial U}{\partial t_i} = -\frac{1}{1+t_i} \sum_{h=1}^{H} \theta^h m^h w_i^h, \tag{A.5}$$

using the result that $\frac{\partial p_i}{\partial t_i} = p_i^0 = \frac{p_i}{1+t_i}$.

Next, let us define fiscal revenues R as

$$R = \sum_{i=1}^{N} p_i^0 t_i \left(\sum_{h=1}^{H} m^h w_i^h\right) = \sum_{i=1}^{N} p_i^0 t_i M_i, \tag{A.6}$$

where M_i represents the aggregate expenditures on commodity i. Assuming a perfect pass-through of tax changes to consumer prices, $\partial p_i^0 / \partial t_i = 0$, the first derivative of R with respect to t_i is shown below.

$$\frac{\partial R}{\partial t_i} = p_i^0 M_i + \sum_{k=1}^{N} p_k^0 t_k \left[\sum_{h=1}^{H} m^h \left(\frac{\partial w_k^h}{\partial p_i}\right)\left(\frac{\partial p_i}{\partial t_i}\right)\right] \tag{A.7}$$

[34] Ahmad and Stern (1984) assume additive taxes: $p = p^0 + t$, which are a somewhat simpler but less realistic tax scheme.

Using the formula for the uncompensated cross-price elasticity and denoting $q_k \equiv \frac{mw_k}{p_k}$, we can rewrite the term as shown below.

$$\frac{\partial w_k^h}{\partial t_i} = \frac{\partial \left(\frac{q_k^h p_k}{m}\right)}{\partial p_i} = \left(\frac{\partial q_k^h}{\partial p_i}\frac{p_k}{q_k}\right)\frac{q_k}{m} = e_{ki}^u \frac{w_k}{p_k} \tag{A.8}$$

Plugging (A.8) and the expression $p_i^0 = \frac{p_i}{1+t_i}$ into (A.7) leads us to the final result for $\partial R/\partial t_i$.

$$\frac{\partial R}{\partial t_i} = \frac{M_i}{1+t_i} + \sum_{k=1}^{N} \frac{t_k}{1+t_k}\left(\sum_{h=1}^{H} m^h \frac{w_k^h e_{ki}^u}{1+t_i}\right) = \frac{M_i}{1+t_i} + \frac{1}{1+t_i}\sum_{k=1}^{N}\frac{M_k e_{ki}^u t_k}{1+t_k} \tag{A.9}$$

Combining the welfare and fiscal revenue effects of a tax change, we arrive at the formula of MWGs similar to Ahmad and Stern (1984)'s.

$$MWG_i^{AS} = -\frac{\partial U/\partial t_i}{\partial R/\partial t_i} = \frac{\sum_{h=1}^{H} \theta^h m^h w_i^h}{M_i + \sum_{k=1}^{N} \frac{M_k e_{ki}^u t_k}{1+t_k}} \tag{A.10}$$

B. Tables

Table B.1: Aggregation of items to broader categories

Category	Items
1 - Bread	Bread products
2 - Other cereals	Rice; Pasta products; Pastry-cook products; Sandwiches; Other products
3 - Unprocessed meat	Fresh, chilled, or frozen meat of bovine animals, swine, sheep, goat, poultry, or fish
4 - Processed meat	Dried, salted or smoked meat, and edible meat offal; Other preserved or processed meat and meat preparations; Other fresh, chilled, or frozen edible meat; Fresh, chilled, or frozen seafood; Dried, smoked, or salted fish and seafood; Other preserved or processed fish and seafood, and fish and seafood preparations
5 - Milk and butter	Whole milk; Low fat milk; Preserved milk; Butter
6 - Other dairy	Yogurt; Cheese and curd; Other milk products; Eggs
7 - Fruits and vegetables	Fresh, chilled, or frozen: Citrus fruits, Bananas, Apples, Pears, Stone fruits, Berries; Other fresh, chilled, or frozen fruits; Dried fruit; Preserved fruits and fruit-based products; Fresh, chilled, or frozen: Leaf and stem vegetables, Cabbages, Vegetables cultivated for their fruit, Root crops, non-starchy bulbs and mushrooms; Dried vegetables; Other preserved or processed vegetables; Potatoes
8 - Other foods	Margarine and other vegetable fats; Olive oil and other edible oils; Other edible animal fats; Sugar; Jams, marmalades; Chocolate; Confectionery products; Edible ices and ice cream; Other sugar products; Sauces; condiments; Salt, spices, and culinary herbs; Baby food, dietary preparations, baker's yeast, and other food preparations
9 - Other non-foods	Non-alcoholic beverages; Alcoholic beverages, tobacco, and narcotics; Clothing and footwear; Housing, water, electricity, gas, and other fuels; Furnishings, household equipment and routine household maintenance; Health; Transport; Communication; Recreation and culture; Education; Restaurants and hotels; Miscellaneous goods and services

Source: Household Budget Survey, Slovak Statistical Office

Table B.2: Description of variables used in QUAIDS

Variable	Definition
w_1, ..., w_9	Budget shares of the nine consumption bundles in the model
P_1, ..., P_9	Price indices of the nine consumption bundles in the model
EXP	Monthly total expenditures of a household
HH_{SIZE}	Household size
AGE	Age of the household head
$GENDER$	Dummy variable: Gender of the household head; 1 if male and 0 if female
$EMPL$	Dummy variable: Employment status of the household head; 1 if employed and 0 otherwise
EDU	Education level of the household head: no or primary education (1), secondary education (2), and tertiary education (3)
$URBAN$	Dummy variable: 1 if household resides in urban area
$CAPITAL$	Dummy variable: 1 if household resides in the capital city
Q_1, ..., Q_4	Seasonal dummy variables
$TREND$	Trend variable (from 2006 to 2012)

Source: Household Budget Survey, Slovak Statistical Office

Table B.3: Descriptive statistics

Variable	2006	2007	2008	2009	2010	2011	2012	Total
w_1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
w_2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
w_3	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.05
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
w_4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
w_5	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
w_6	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
w_7	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
w_8	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
w_9	0.74	0.74	0.74	0.75	0.75	0.75	0.75	0.75
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)
EXP	706.18	726.05	775.65	753.36	766.63	794.03	825.56	763.71
	(363.77)	(373.53)	(386.19)	(370.20)	(381.54)	(382.51)	(373.89)	(377.94)
P_1	1.63	1.67	1.76	1.71	1.63	1.67	1.66	1.68
	(0.30)	(0.33)	(0.37)	(0.38)	(0.38)	(0.39)	(0.42)	(0.37)
P_2	2.87	2.87	2.89	2.86	2.81	2.85	2.87	2.86
	(0.65)	(0.67)	(0.73)	(0.75)	(0.79)	(0.84)	(0.86)	(0.76)
P_3	4.56	4.57	4.67	4.44	4.33	4.51	4.69	4.54
	(0.81)	(0.77)	(0.77)	(0.74)	(0.73)	(0.77)	(0.79)	(0.78)
P_4	5.55	5.50	5.51	5.46	5.32	5.46	5.65	5.49
	(0.76)	(0.76)	(0.76)	(0.78)	(0.76)	(0.77)	(0.81)	(0.78)
P_5	2.59	2.60	2.55	2.39	2.47	2.62	2.56	2.54
	(0.97)	(1.05)	(1.12)	(1.10)	(1.19)	(1.29)	(1.23)	(1.14)
P_6	4.49	4.52	4.64	4.36	4.35	4.51	4.59	4.49
	(0.61)	(0.66)	(0.68)	(0.65)	(0.68)	(0.74)	(0.71)	(0.68)
P_7	2.55	2.57	2.57	2.44	2.49	2.55	2.58	2.53
	(0.64)	(0.64)	(0.65)	(0.63)	(0.59)	(0.69)	(0.72)	(0.65)
P_8	5.04	5.02	4.85	5.00	4.92	4.88	4.97	4.95
	(1.32)	(1.42)	(1.42)	(1.56)	(1.52)	(1.50)	(1.56)	(1.48)
P_9	6.65	8.18	11.25	13.32	13.72	18.21	22.14	13.29
	(1.84)	(2.10)	(2.71)	(3.60)	(3.66)	(4.59)	(4.56)	(6.00)
HH_{SIZE}	2.91	2.85	2.85	2.90	2.91	2.91	2.97	2.90
	(1.40)	(1.40)	(1.43)	(1.43)	(1.40)	(1.41)	(1.42)	(1.42)
AGE	54.43	53.41	52.86	52.42	53.37	53.74	53.34	53.35
	(14.26)	(14.29)	(14.44)	(14.04)	(14.17)	(14.29)	(13.75)	(14.19)
$GENDER$	0.70	0.68	0.68	0.68	0.69	0.68	0.71	0.69
	(0.46)	(0.47)	(0.47)	(0.47)	(0.46)	(0.46)	(0.46)	(0.46)
$EMPL$	0.66	0.66	0.67	0.67	0.60	0.62	0.66	0.65
	(0.47)	(0.47)	(0.47)	(0.47)	(0.49)	(0.48)	(0.47)	(0.48)
EDU	1.13	1.13	1.89	1.91	2.01	2.05	2.06	1.74
	(0.33)	(0.33)	(0.32)	(0.29)	(0.46)	(0.47)	(0.45)	(0.55)
$URBAN$	0.61	0.59	0.60	0.58	0.55	0.55	0.53	0.57
	(0.49)	(0.49)	(0.49)	(0.49)	(0.50)	(0.50)	(0.50)	(0.49)
$CAPITAL$	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.11
	(0.33)	(0.33)	(0.32)	(0.31)	(0.32)	(0.31)	(0.30)	(0.32)
Q_1	0.24	0.24	0.24	0.26	0.24	0.25	0.27	0.25
	(0.43)	(0.43)	(0.43)	(0.44)	(0.43)	(0.44)	(0.44)	(0.43)
Q_2	0.26	0.25	0.25	0.25	0.26	0.25	0.25	0.25
	(0.44)	(0.44)	(0.44)	(0.44)	(0.44)	(0.43)	(0.43)	(0.44)
Q_3	0.25	0.25	0.25	0.24	0.25	0.25	0.24	0.25
	(0.43)	(0.43)	(0.43)	(0.43)	(0.43)	(0.43)	(0.43)	(0.43)
Q_4	0.26	0.25	0.25	0.25	0.24	0.24	0.24	0.25
	(0.44)	(0.44)	(0.43)	(0.43)	(0.43)	(0.43)	(0.43)	(0.43)
N	3,675	4,003	4,061	3,988	5,211	3,888	3,534	28,360

Note: Standard deviations are presented in parentheses. Descriptive statistics are computed using survey weights.
Source: Household Budget Survey, Slovak Statistical Office

Table B.4: QUAIDS parameters estimates, pooled sample (2006-2012)

Parameter	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9
γ									
P_1 (ln)	0.013***	0.003***	-0.002*	-0.001	-0.001*	0.008***	0.008***	0.006***	-0.034***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)
P_2 (ln)	-0.000	0.009***	-0.012***	0.000	-0.002***	-0.001*	-0.003***	-0.008***	0.016***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.002)
P_3 (ln)	-0.000	0.003**	0.031***	-0.004***	0.001	0.002**	0.003*	0.001	-0.038***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.007)
P_4 (ln)	-0.005***	-0.002**	-0.005***	-0.006***	0.001	0.003***	0.002	-0.004***	0.018**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.006)
P_5 (ln)	-0.001***	-0.001***	-0.001**	0.001	0.004***	0.001***	0.002***	-0.000	-0.004**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
P_6 (ln)	0.001	-0.000	0.002	0.005***	-0.001	0.006***	-0.001	-0.001	-0.012**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
P_7 (ln)	-0.002***	-0.000	-0.008***	0.001*	0.000	0.001	-0.003***	0.005***	0.006
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)
P_8 (ln)	-0.003***	-0.004***	-0.014***	-0.003***	-0.002***	0.000	-0.000	0.003***	0.023***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)
P_9 (ln)	-0.009***	-0.002*	0.004***	-0.003**	-0.004***	-0.005***	-0.002	-0.002**	0.022***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.006)
β	-0.007	-0.003	0.026**	0.013	-0.002	0.003	0.012	0.012	-0.053
	(0.013)	(0.010)	(0.009)	(0.007)	(0.011)	(0.008)	(0.011)	(0.008)	(0.074)
λ	-0.001	-0.000	-0.004***	-0.003***	-0.001	-0.002	-0.002	-0.002**	0.015
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)
α									
HH_{SIZE}	0.006***	0.002***	0.002***	0.003***	0.003***	0.003***	0.001***	0.003***	-0.023***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
AGE	0.000***	0.000	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$GENDER$	0.002***	-0.000	0.003***	0.004***	0.001**	-0.000	-0.001**	0.000	-0.009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
$EMPL$	-0.002***	-0.001***	-0.003***	-0.001***	-0.002***	-0.000	-0.003***	-0.004***	0.016***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
EDU	-0.001***	-0.001***	-0.006***	-0.003***	0.000	0.001***	0.000	-0.003***	0.012***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$URBAN$	-0.005***	-0.002***	-0.004***	-0.004***	-0.003***	0.002***	0.007***	-0.005***	0.014***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$TREND$	0.000	0.000	-0.001***	-0.000	-0.000***	-0.000	-0.000*	-0.000**	0.002*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$CAPITAL$	-0.002***	0.001***	0.001	-0.004***	-0.001***	0.002***	0.002***	-0.004***	0.004*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Q_2	0.000	-0.000	-0.000	0.000	-0.001***	-0.001***	0.003***	0.003***	-0.004**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Q_3	0.001*	-0.000	0.001	-0.001*	-0.001***	-0.002***	0.000	0.005***	-0.002
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Q_4	0.001**	0.000	0.004***	0.001**	-0.000	-0.002***	0.001	0.005***	-0.010***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
$CONSTANT$	-0.410	0.021	1.966***	0.220	0.933***	0.205	0.699*	0.843**	-3.477
	(0.335)	(0.257)	(0.403)	(0.275)	(0.279)	(0.251)	(0.354)	(0.300)	(1.920)
R^2	0.312	0.160	0.160	0.130	0.173	0.145	0.111	0.181	0.291

Note: 1 - Bread, 2 - Other cereals, 3 - Unprocessed meat, 4 - Processed meat, 5 - Milk and butter, 6 - Other dairy, 7 - Fruits and vegetables, 8 - Other foods, 9 - Other non-foods. Sample size includes 28,360 observations. Outliers (1%) in expenditure and prices were trimmed. Variable Q_1 was omitted from regressions due to the collinearity problem. Standard errors are presented in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Household Budget Survey, Slovak Statistical Office

Table B.5: Fitted budget shares and price elasticities

	1	2	3	4	5	6	7	8	9
					Budget shares				
	0.032***	0.018***	0.047***	0.033***	0.016***	0.033***	0.037***	0.042***	0.740***
					Budget elasticities				
	0.424***	0.620***	0.776***	0.664***	0.467***	0.640***	0.762***	0.711***	1.121***
					Uncompensated price elasticities				
	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9
w_1	-0.536***	0.034**	-0.001	-0.114***	0.014	0.075***	-0.026*	-0.035	0.295
w_2	0.224***	-0.475***	0.159***	-0.093***	-0.013	0.005	0.011	-0.176***	0.244
w_3	0.022	-0.201***	-0.308***	-0.030	0.011	0.098**	-0.106***	-0.221***	0.650*
w_4	0.050*	0.062***	-0.085***	-1.113***	0.058***	0.202***	0.092***	0.003	0.528*
w_5	0.010	-0.103**	0.101*	0.105***	-0.748***	-0.007	0.069***	-0.056	0.297
w_6	0.301***	0.013	0.081***	0.140***	0.064***	-0.772***	0.062***	0.064***	0.339
w_7	0.273***	-0.033	0.095***	0.097***	0.090***	0.017	-1.046***	0.062*	0.406
w_8	0.199***	-0.145***	0.055***	-0.040	0.032**	0.018	0.169***	-0.852***	0.428*
w_9	-0.068***	0.007	-0.058***	0.003	-0.018***	-0.031***	-0.008*	0.007	-1.151***
					Compensated price elasticities				
	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9
w_1	-0.523***	0.042**	0.019	-0.099***	0.021*	0.090***	-0.010	-0.017	0.608
w_2	0.244***	-0.463***	0.188***	-0.072**	-0.003	0.026	0.034*	-0.150***	0.702
w_3	0.047	-0.187***	-0.271***	-0.004	0.024	0.124***	-0.078***	-0.188***	1.224***
w_4	0.072**	0.074***	-0.054	-1.091***	0.069***	0.224***	0.117***	0.031	1.019***
w_5	0.025	-0.094**	0.123**	0.121***	-0.740***	0.008	0.086***	-0.036	0.642
w_6	0.322***	0.025*	0.111***	0.162***	0.075***	-0.751***	0.086***	0.091***	0.813***
w_7	0.298***	-0.019	0.131***	0.122***	0.102***	0.043	-1.018***	0.094***	0.969***
w_8	0.222***	-0.131***	0.089***	-0.016	0.044***	0.041*	0.195***	-0.823***	0.954***
w_9	-0.032***	0.028***	-0.005	0.040***	0.000	0.007	0.033***	0.054***	-0.322***

Note: 1 - Bread, 2 - Other cereals, 3 - Unprocessed meat, 4 - Processed meat, 5 - Milk and butter, 6 - Other dairy, 7 - Fruits and vegetables, 8 - Other foods, 9 - Other non-foods. Own-price elasticities are highlighted by gray color. Standard errors are presented in parentheses. $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.
Source: Household Budget Survey, Slovak Statistical Office

Table B.6: Demand responses to a VAT cut from 20% to 10% - individual bundles

	(1)	(2)	(3)	(4)	(5)	(6)
	Initial nominal exp. on i	Initial fitted bud. shares of i	New fitted bud. shares of i	Change in nominal exp. on i	Change in real exp. on i	Uncomp. own-price elasticity of i
VAT cut for bundle i:	mw_i (EUR/month)	$w_i(p)$ (%)	$w_i(\tau p_i, p_{-i})$ (%)	mw_i (%)	$mw_i/\tau p_i$ (%)	8.3%. e^u_{ij} (%)
1 Bread	21.90	3.19	3.07	-4.61	4.07	4.42
2 Other cereals	12.86	1.84	1.76	-4.81	3.85	3.92
3 Unprocessed meat	31.70	4.60	4.31	-6.89	1.58	2.50
4 Processed meat	22.64	3.26	3.31	1.39	10.61	9.25
5 Milk and butter	11.15	1.63	1.60	-2.50	6.36	6.17
6 Other dairy	22.98	3.30	3.24	-1.92	7.00	6.42
7 Fruits and vegetables	25.07	3.62	3.64	0.60	9.74	8.67
8 Other food	28.53	4.13	4.09	-1.07	7.93	7.08
9 Other non-food	566.45	74.42	74.57	0.21	9.32	9.58

Note: Sample means.
Source: Household Budget Survey, Slovak Statistical Office

Table B.7: Demand responses to a VAT cut from 20% to 10% - multiple bundles

VAT cut for bundles i:	(1) Initial nominal exp. on i	(2) Initial fitted bud. shares of i	(3) New fitted bud. shares of i	(4) Change in nominal exp. on i	(5) Change in real exp. on i	(6) Uncomp. own-price elasticity of i
	mw_i (EUR/month)	$w_i(p)$ (%)	$w_i(\tau p_i, p_{-i})$ (%)	mw_i (%)	$mw_i/\tau p_i$ (%)	8.3%. e_{ij}^u (%)
1, 3, 5 - the 2016 VAT cut	64.75	9.42	8.99	-4.97	3.80	3.81
2, 4, 5, 7, 8	100.26	14.49	14.43	-0.47	5.35	7.49
2, 5, 7	49.08	7.10	7.01	-1.25	7.32	6.90
1 - 8	176.84	25.58	24.93	-2.71	5.65	6.12

Note: sample means; column (6) reports weighted average elasticities of the involved bundles using fitted new budget shares as weights.
Key: 1 - Bread, 2 - Other cereals, 3 - Unprocessed meat, 4 - Processed meat, 5 - Milk and butter, 6 - Other dairy, 7 - Fruits and vegetables, 8 - Other foods, 9 - Other non-foods.
Source: Household Budget Survey, Slovak Statistical Office

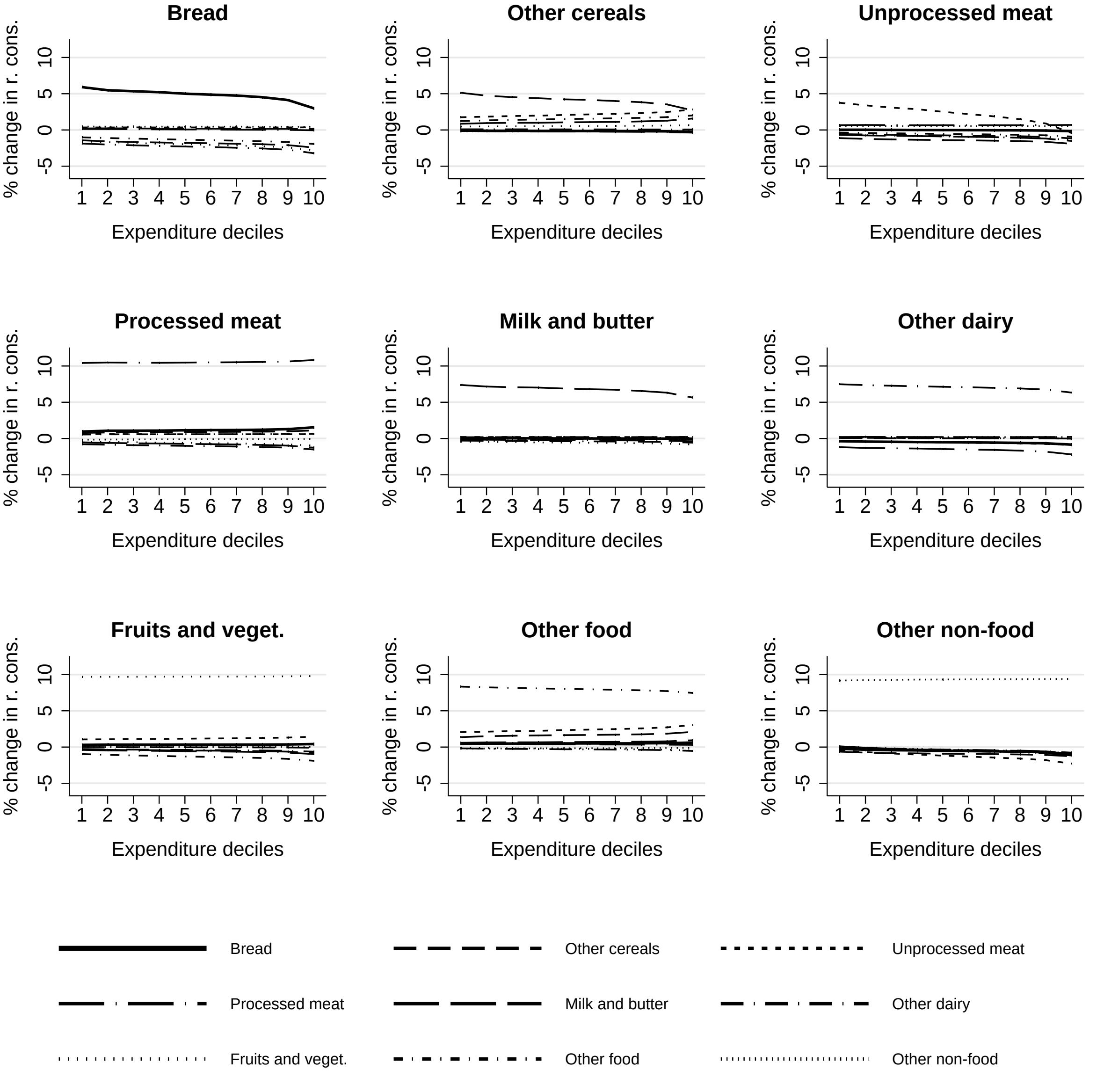
Table B.8: Welfare gains from revenue-neutral VAT cuts (from 20% to 0%)

VAT cut to 0% for bundles:	(1) VAT rate on non-food	(2) Revenue-neutral welfare impact (EUR/month)	(3) (rank)	(4) MWG by QUAIDS (rank)
1 Bread	20.70%	-0.78	6	7
2 Other cereals	20.42%	1.28	3	2
3 Unprocessed meat	20.96%	-2.43	8	8
4 Processed meat	20.81%	2.99	2	1
5 Milk and butter	20.34%	0.68	5	5
6 Other dairy	20.79%	-1.05	7	6
7 Fruits and vegetables	20.88%	1.08	4	4
8 Other foods	20.96%	3.06	1	3
1, 3, 5 - the 2016 VAT cut	21.99%	-2.49	4	4
2, 4, 5, 7, 8	23.47%	9.05	1	1
2, 5, 7	21.65%	3.03	3	2
1 - 8	25.79%	5.39	2	3

Note: Sample means.
Source: Household Budget Survey, Slovak Statistical Office

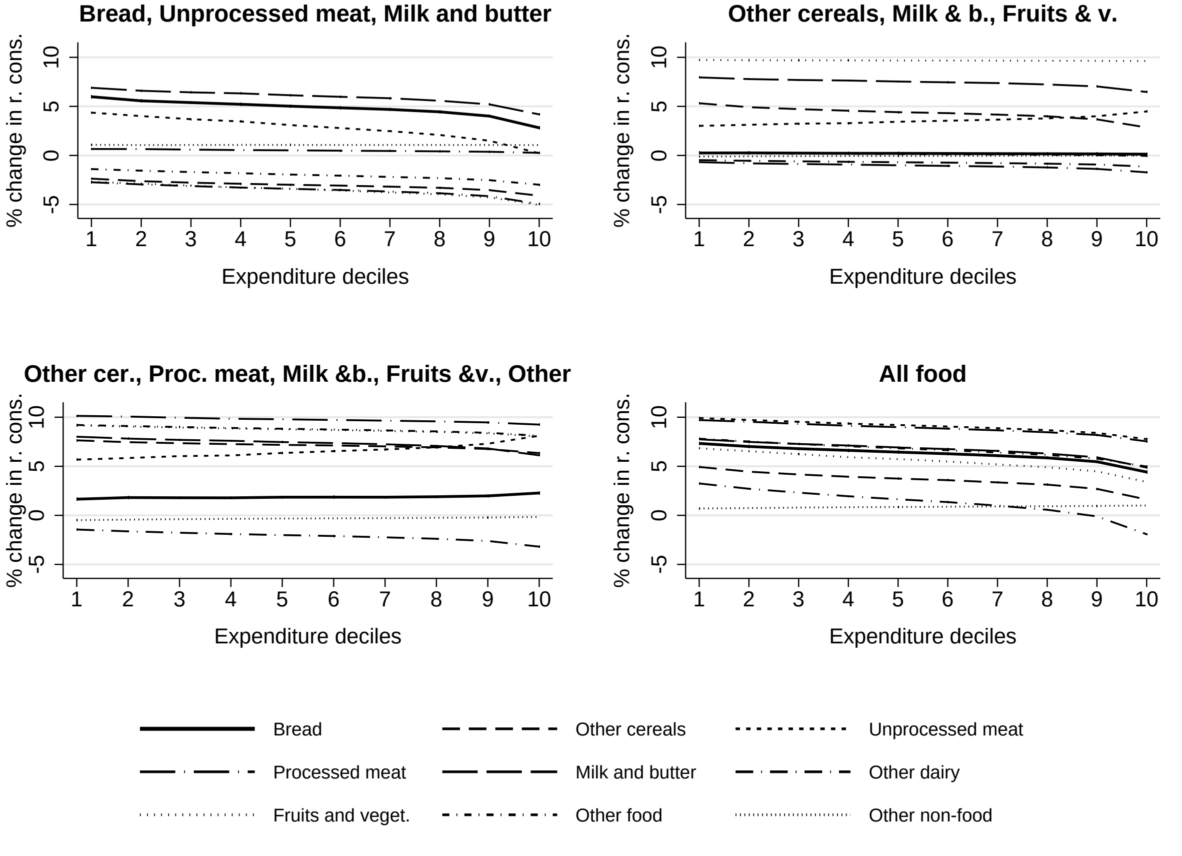
C. Figures

Figure 1: Changes in real consumption - VAT cut from 20% to 10% for individual bundles



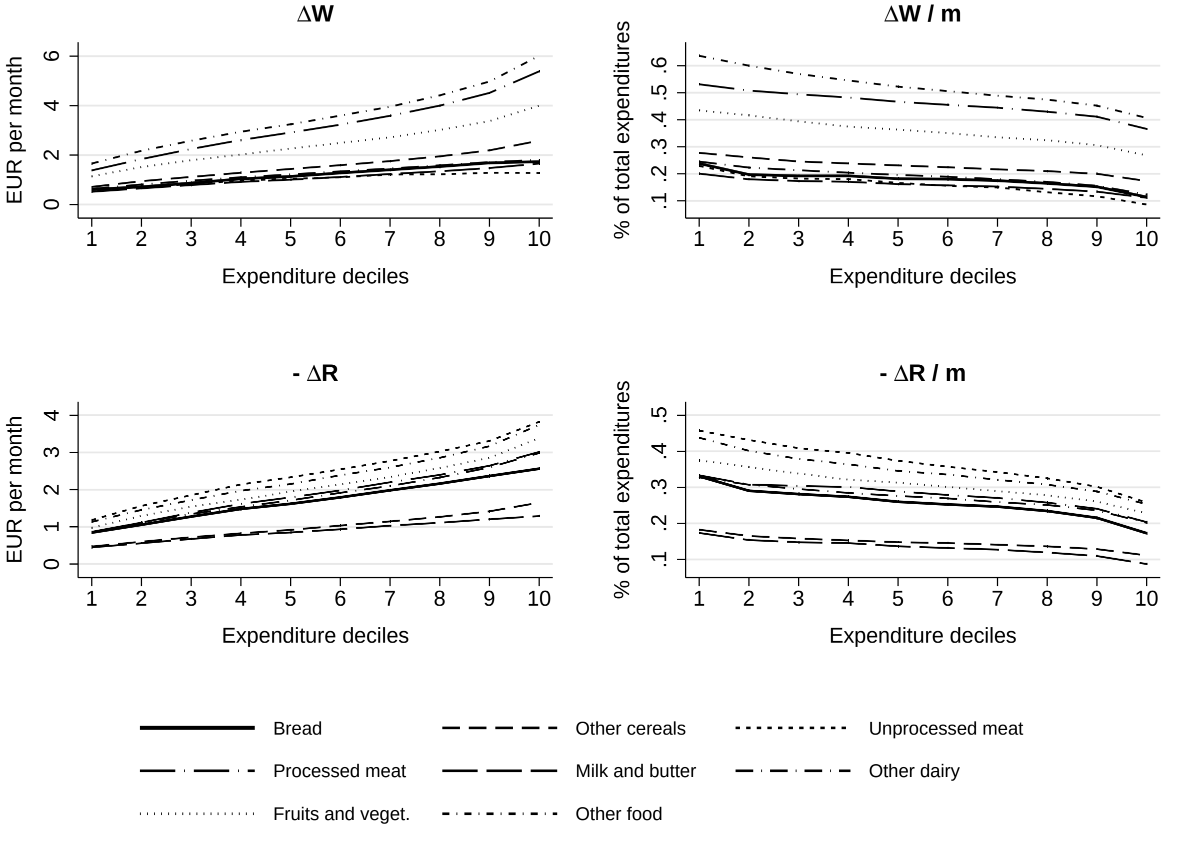
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 2: Changes in real consumption - VAT cut from 20% to 10% for multiple bundles



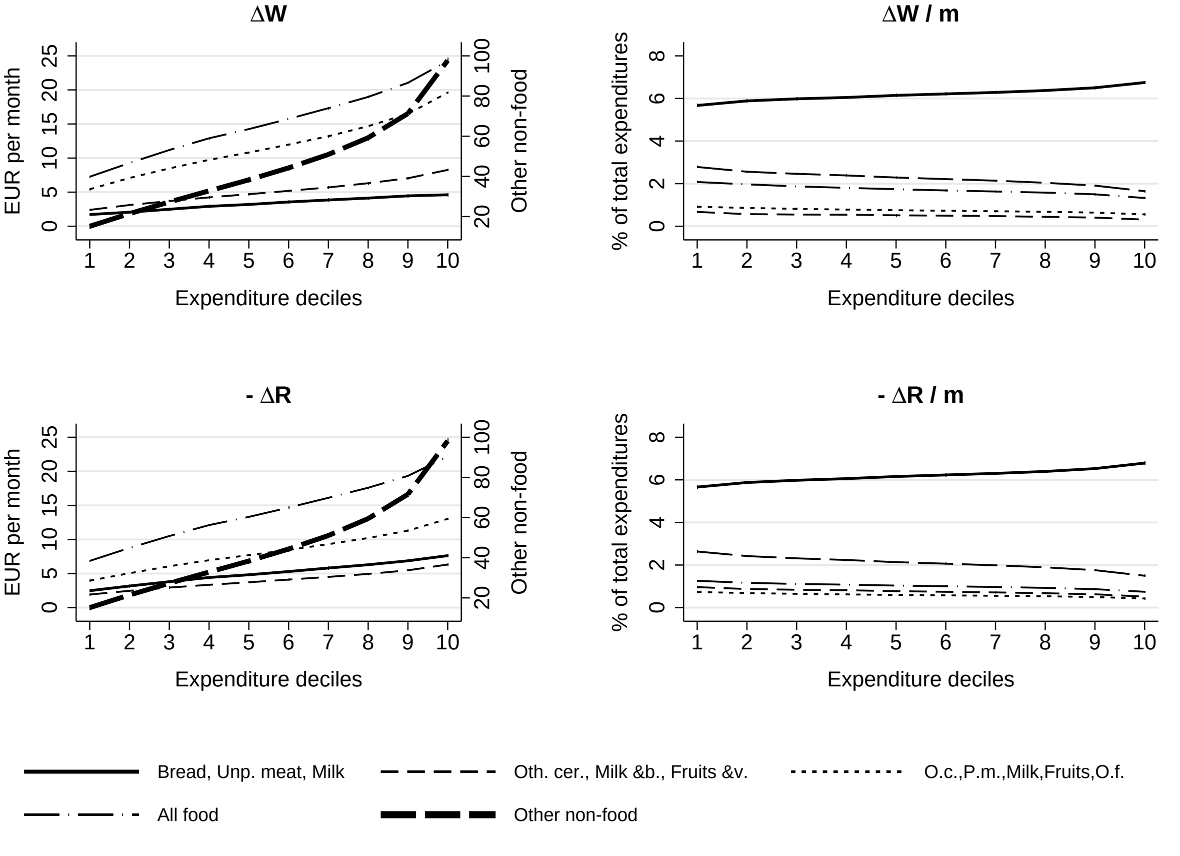
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 3: Welfare and fiscal impacts of a VAT cut from 20% to 10% for individual bundles



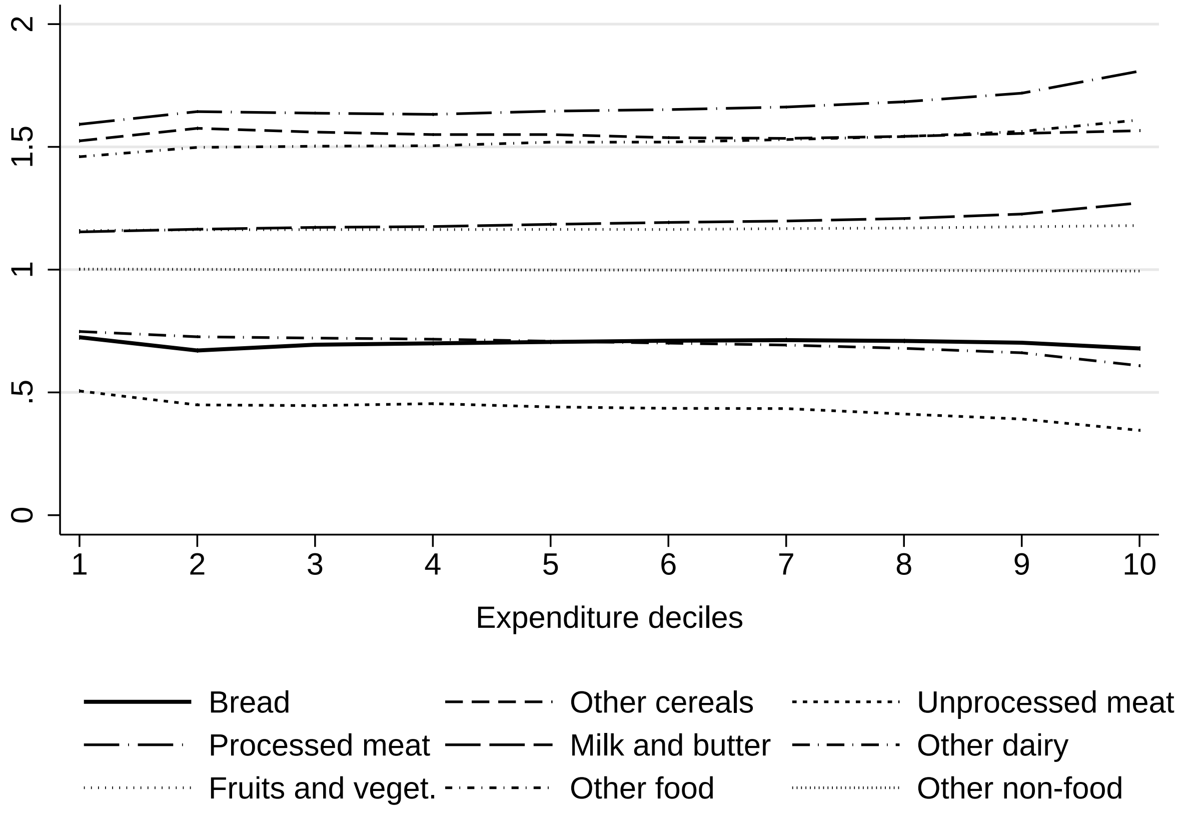
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 4: Welfare and fiscal impacts of a VAT cut from 20% to 10% for multiple bundles



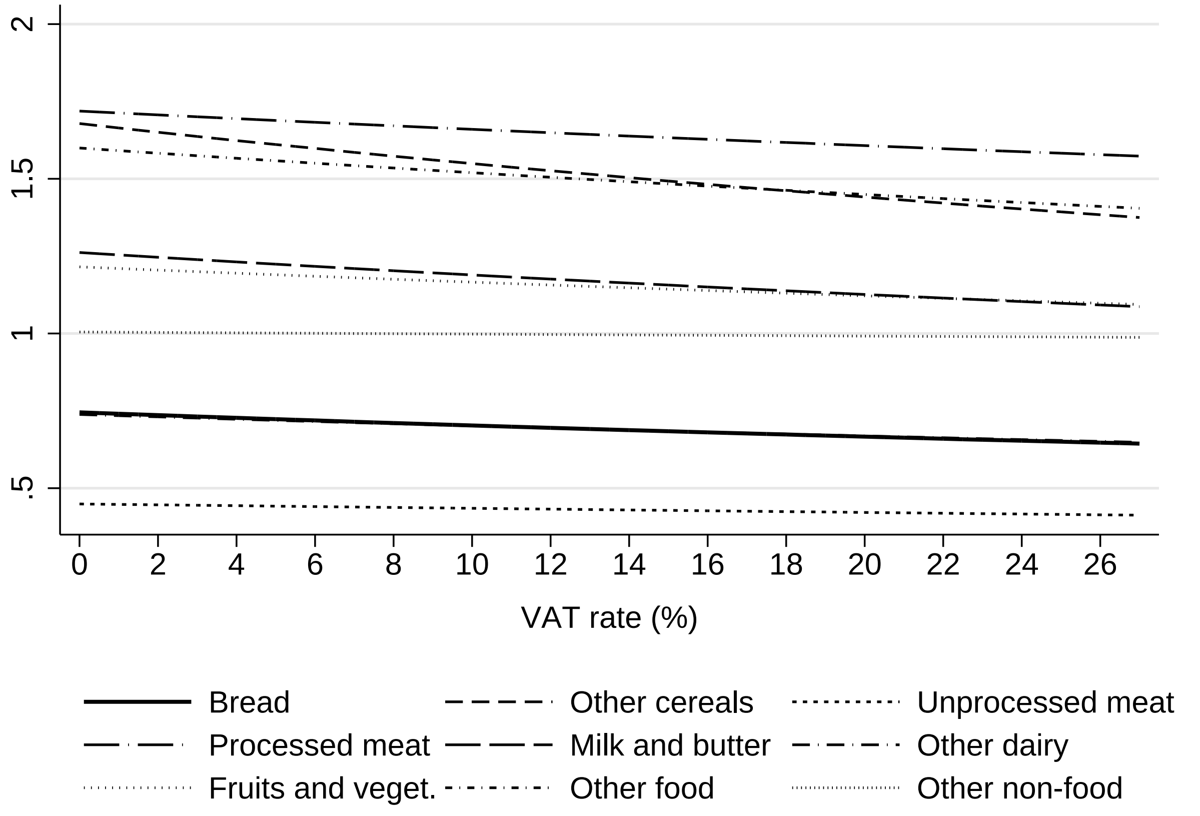
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 5: Marginal welfare gains by expenditure deciles



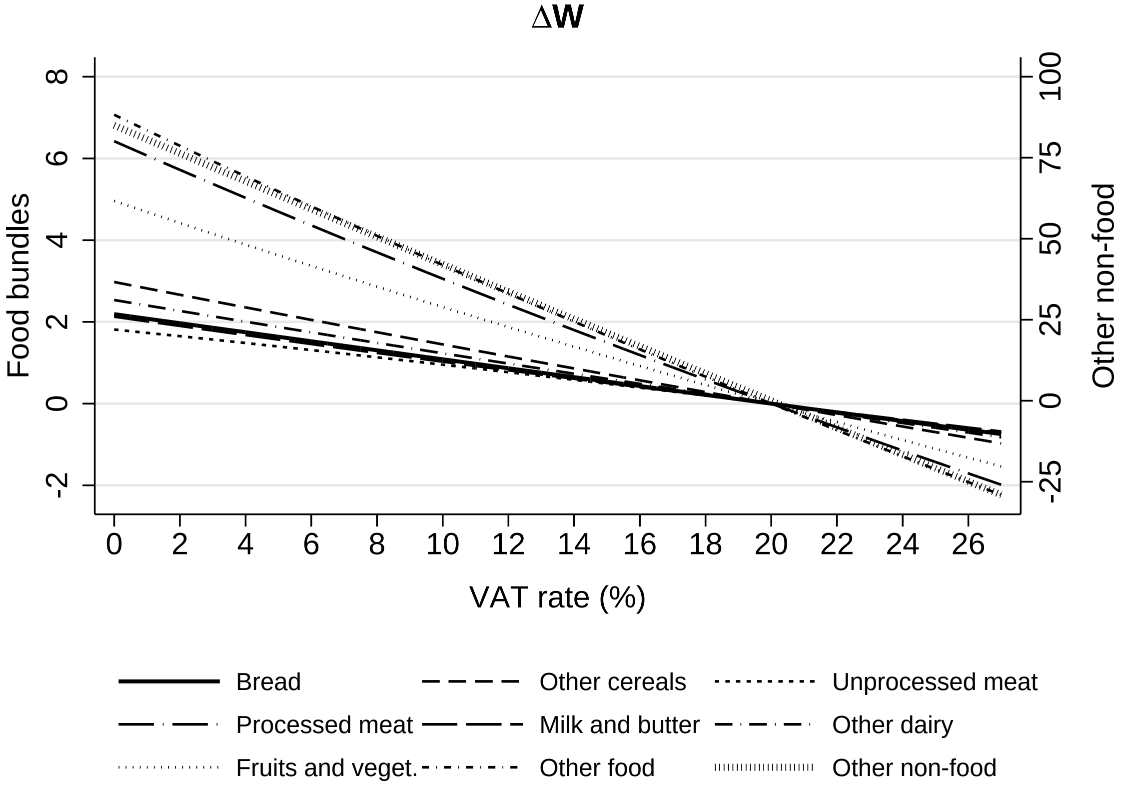
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 6: Marginal welfare gains by VAT rates



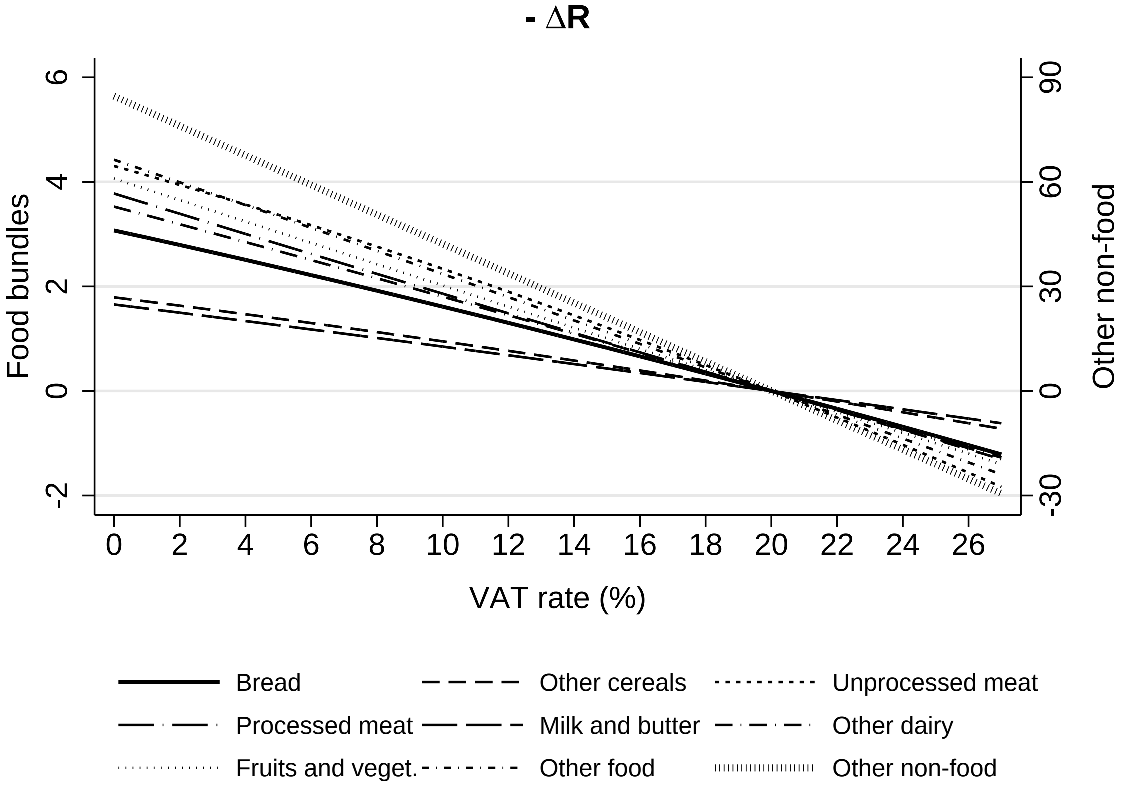
Note: The curves are not defined for a 20% VAT rate. Sample means are displayed.
Source: Household Budget Survey, Slovak Statistical Office

Figure 7: Welfare impacts by VAT rates



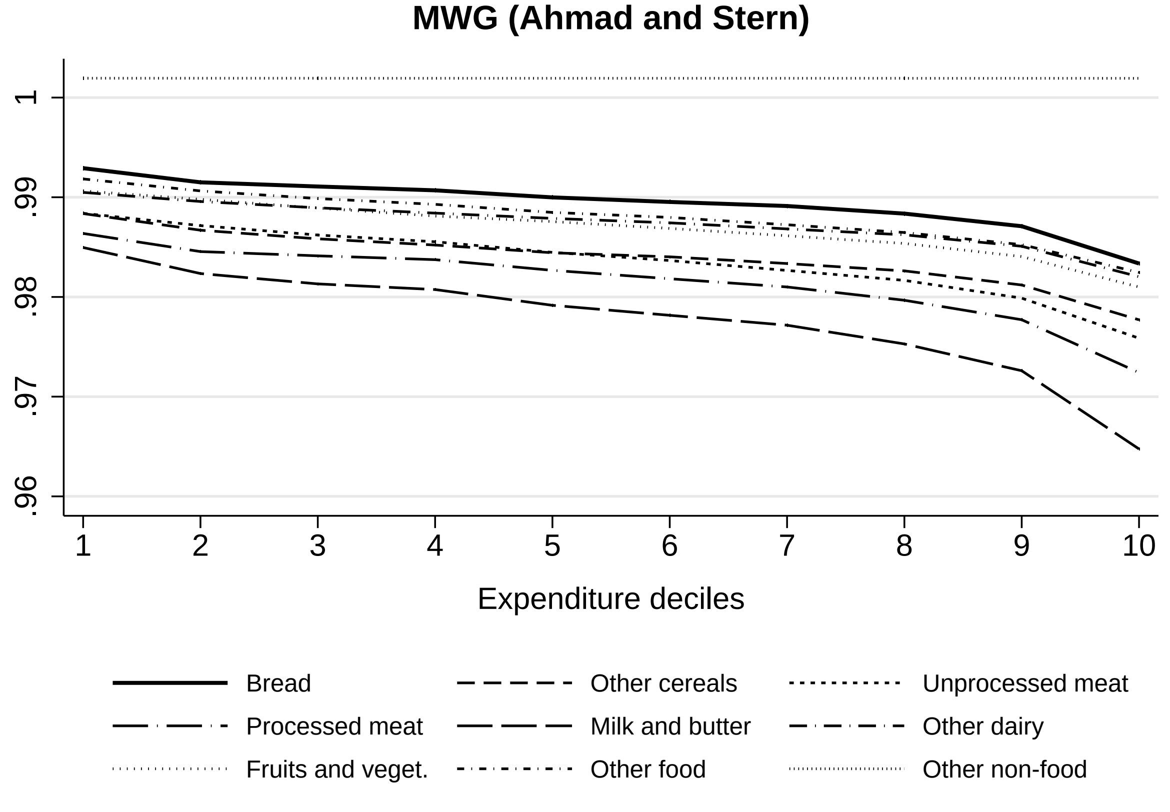
Note: Sample means in EUR per month and household.
Source: Household Budget Survey, Slovak Statistical Office

Figure 8: Fiscal impacts by VAT rates



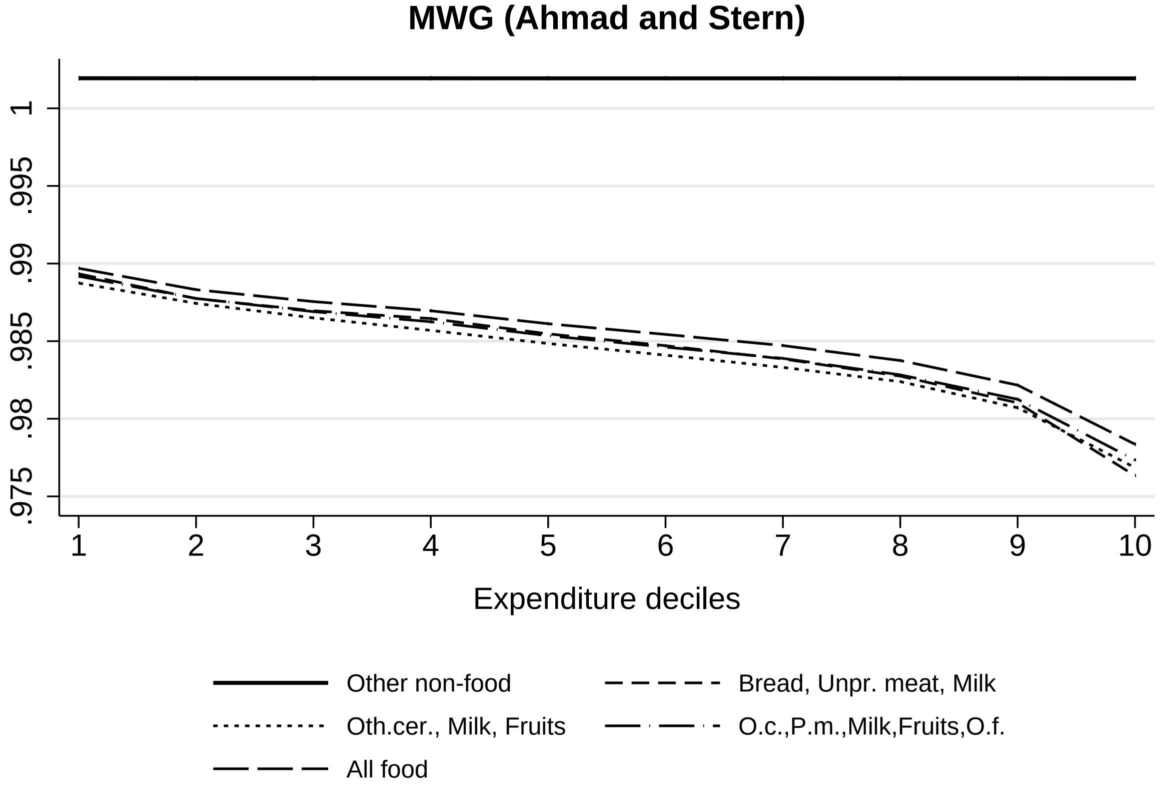
Note: Sample means in EUR per month and household.
Source: Household Budget Survey, Slovak Statistical Office

Figure 9: Marginal welfare gains of a VAT cut from 20% to 10% for individual bundles



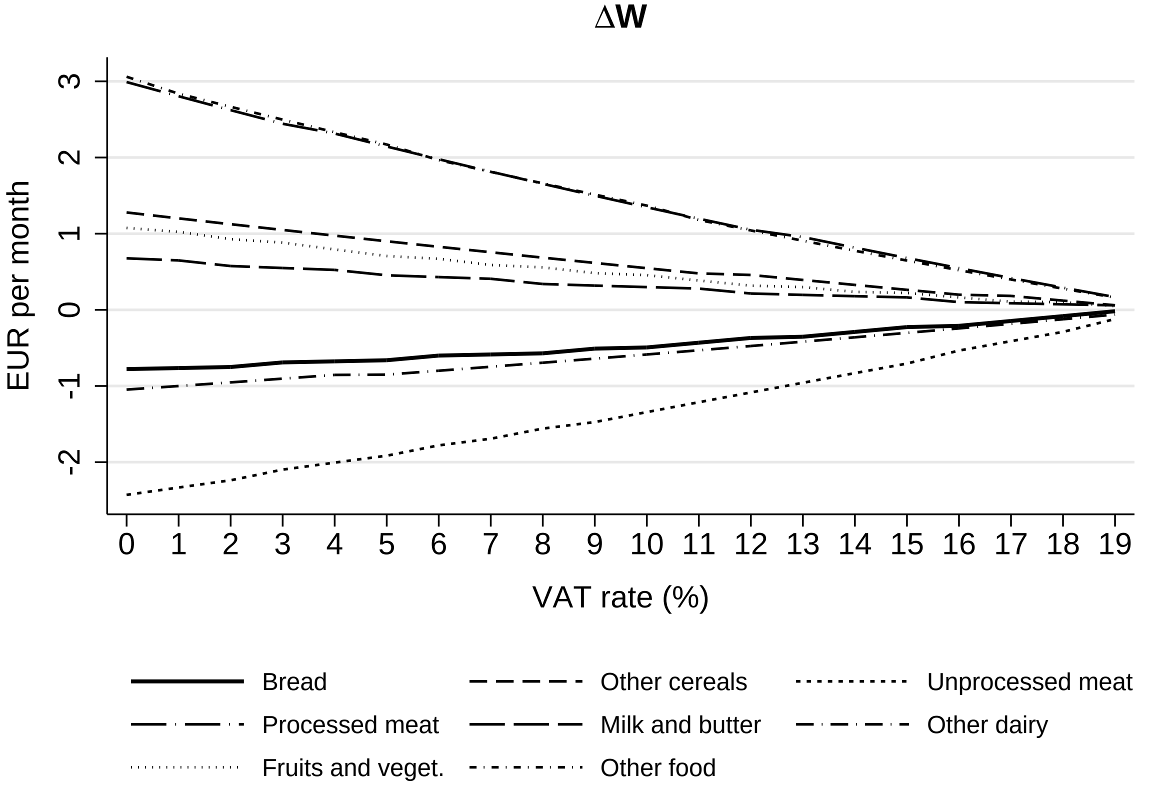
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 10: Marginal welfare gains of a VAT cut from 20% to 10% for multiple bundles



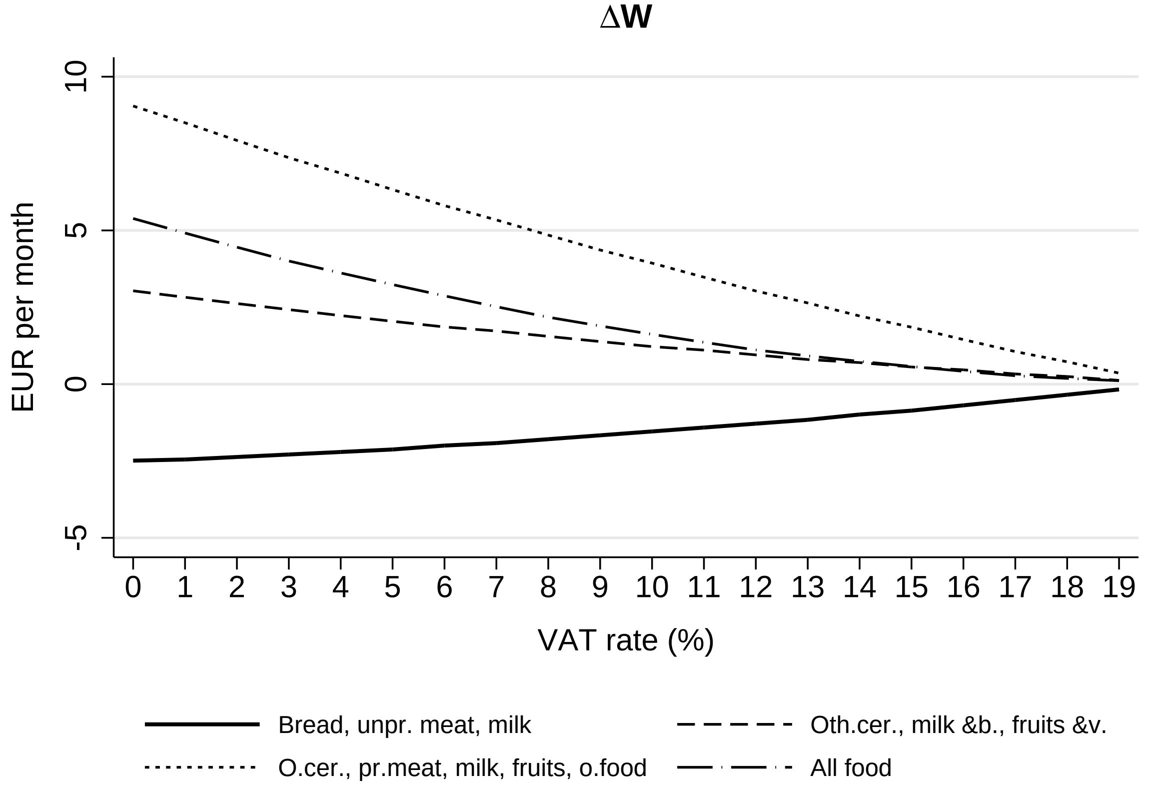
Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 11: Revenue-neutral welfare impacts by VAT rates on food for individual bundles



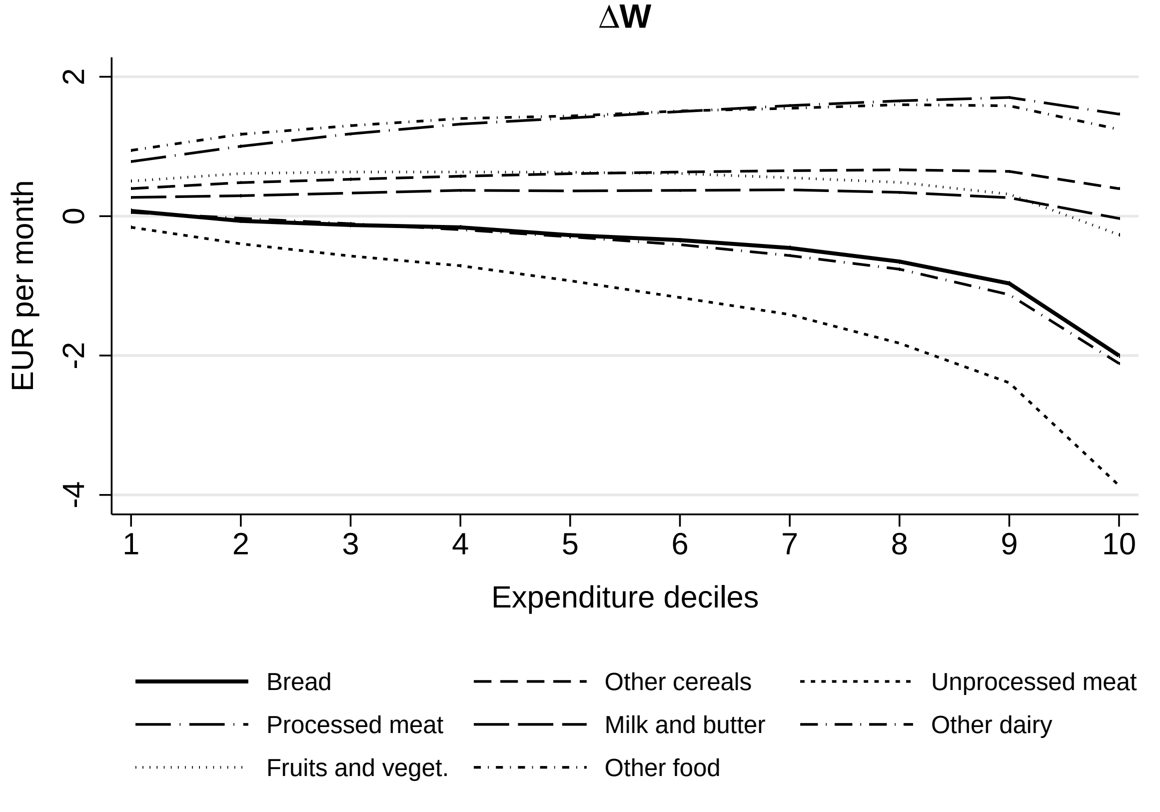
Note: Sample means.
Source: Household Budget Survey, Slovak Statistical Office

Figure 12: Revenue-neutral welfare impacts by VAT rates on food for multiple bundles



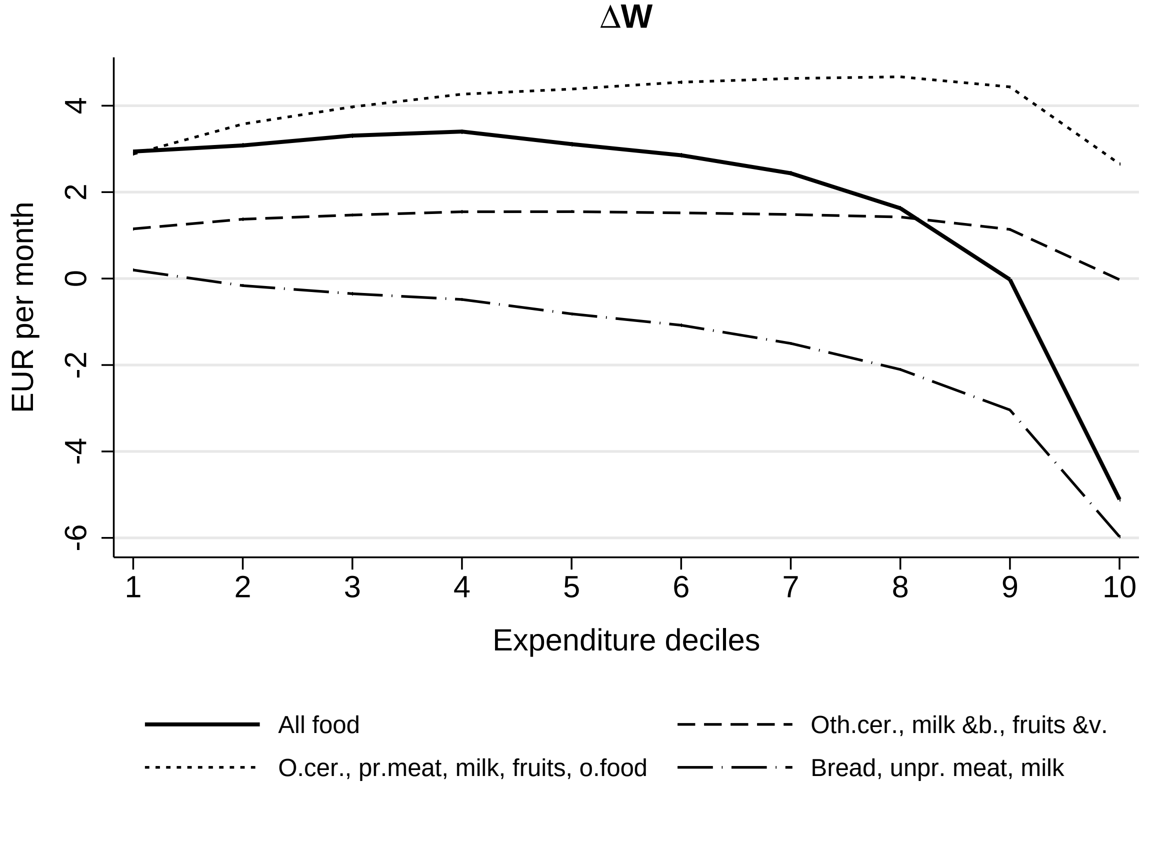
Note: Sample means.
Source: Household Budget Survey, Slovak Statistical Office

Figure 13: Revenue-neutral welfare impacts of a VAT cut from 20% to 10% by expenditure deciles (individual bundles)



Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office

Figure 14: Revenue-neutral welfare impacts of a VAT cut from 20% to 10% by expenditure deciles (multiple bundles)



Note: Median values for each decile.
Source: Household Budget Survey, Slovak Statistical Office