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Article — Manuscript Version (Preprint)

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Oxford Economic Papers

Suggested Citation: Tóth, Peter; Cupák, Andrej; Rizov, Marian (2021) : Measuring the Efficiency of VAT Reforms: A Demand System Simulation Approach, Oxford Economic Papers, ISSN 1464-3812, Oxford University Press, Oxford, Vol. 73, Iss. 3, pp. 1218-1243, <https://doi.org/10.1093/oep/gpaa052>

This Version is available at:

<https://hdl.handle.net/10419/233895>

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Measuring the Efficiency of VAT Reforms: A Demand System Simulation Approach

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Abstract

Using an estimated demand model, we simulate household-level demand responses to the recent Slovak VAT reform and its hypothetical alternatives. We use simulation results, instead of the standard approximate measures, for constructing an improved efficiency indicator of tax reforms as a ratio of welfare and fiscal revenue effects and call it marginal welfare gain. We also contribute to the literature on optimal structure of indirect taxes and on marginal tax reforms with new evidence of actual and hypothetical reforms that could increase the welfare of households at zero fiscal costs. Regarding the general policy implications of our results we conclude that using a demand model to rank commodities according to their marginal welfare gains can be helpful for designing both efficient and equitable VAT reforms.

JEL classification: D12; H21; H31.

Keywords: consumer behavior; demand system; VAT reforms; equity; efficiency.

1 Introduction

Consumption taxes represent a significant source of tax revenues, especially in developed countries. Consumption taxation raises the highest share, averaging around one third, of the tax revenues in OECD countries (Decoster et al., 2010). Hence, consumption taxes feature prominently in the optimal tax structure debates, associated with equity and efficiency considerations. A typical argument in favour of consumption taxes suggests taxing commodities with negative externalities, such as alcohol, tobacco, unhealthy foods or pollution. Furthermore, taxing consumption can be viewed as equivalent to taxing leisure, which is less distortive for production than taxing income or labour (see e.g., Bosch and van den Noord, 1990).

A related stream of the literature looks at 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 changes consumer behaviour the most. Therefore, consumers incur larger deadweight losses in such cases which leads to a more severe allocative inefficiency. Since price elasticities vary across commodities, a differentiated tax scheme, which better reflects demand characteristics, than applying a uniform rate, could be a relatively more efficient approach while considering other, social goals. In other words, a differentiated tax scheme could allow pursuing multiple goals such as a more equitable distribution and positive externality support while balancing these against minimal efficiency losses.

Because estimating the optimal structure of consumption taxes is not feasible in practice, Ahmad and Stern (1984) has turned the academic discussion towards marginal tax reforms.¹

¹ For a survey of the more recent literature on marginal tax reforms see Santoro (2007). A non-exhaustive list of studies 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 (1996; 1997) and Savage (2016) for Ireland, Urakawa and Oshio (2010) for Japan and South Korea, Ray (1999) for Australia, and Urzúa (2005) for Mexico.

The aim is to identify incremental changes in a tax system which are welfare-improving and have a neutral effect on fiscal revenues. Such findings could indicate directions of changes in the tax system that are efficient. For this purpose, one first needs to 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 the revenue loss by tax increases on less socially costly goods. The efficiency ranking of goods requires estimates of price elasticities of demand, which are typically obtained by fitting a demand system on detailed household level consumption data. Most of the recent applications estimate the Quadratic Almost Ideal Demand System (QUAIDS) of Banks et al. (1997).²

We contribute to the literature by proposing an improved estimation of the efficiency ranking. The improvement stems from computing the marginal welfare gain (the ratio of welfare and fiscal revenue impacts) via simulations using the QUAIDS demand system. The standard practice in the literature is to use approximate measures based on comparative statics (average elasticities). In particular, the existing papers rely on so-called first- and second-order approximations of the welfare and fiscal revenue impacts which are based on price elasticities. We argue that the efficiency indicator calculated as a ratio of proxy measures leads to a biased ranking of goods. The bias results from the fact that approximate welfare impacts ignore or assume imprecise demand responses. Therefore, welfare impacts directly estimated from a demand model using measures such as compensating (or equivalent) variation are preferable (see Banks et al., 1996). Furthermore, we argue that the approximate fiscal impacts based on price elasticities³ are also biased compared to simulated values from a demand model such as QUAIDS that we use, for any realistic degree of a VAT change.

² This is the quadratic extension of the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980).

³ For studies calculating such approximate fiscal impacts see, e.g., García-Enríquez and Echevarría (2016, 2018) for Spain and Janský (2014) for the Czech Republic.

To the best of our knowledge, our paper is the first to use consistently demand-system simulation results in the computation of an efficiency indicator that can be used to inform efficient and equitable tax reform designs. Our novelty lies in bringing together the well-established literature on welfare impact analysis, based on parameters estimated from a demand system such as QUAIDS (e.g., Banks et al., 1996; 1997) and our idea of simulating also the fiscal impacts from the demand-system. Thus, we contribute to the literature on the optimal structure of consumption taxes where papers commonly use approximate measures based on comparative statics, often ignoring the specificities of the demand responses.⁴

As an additional contribution to the literature, we provide new evidence of potential revenue-neutral, welfare-improving tax reforms in Slovakia. Following on twenty years of transition, the Slovak economy has successfully converged towards the developed country group and it provides a good example for the (aspiring) developing countries in their quest for improving tax efficiency and welfare. In this paper we apply a QUAIDS for eight food bundles and a non-food consumption aggregate using Slovak household-level data. The structure of the model is motivated by the recent VAT reform in Slovakia, in 2016, which reduced the standard rate of 20% to 10% for selected food categories. In particular, the reduced rate was applied to 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. Given that Slovakia was one of the few countries with a close to⁵ uniform VAT rate before the reform took place, and the share of households' spending on food was one of the highest in the EU, our approach is not only of statistical, but most importantly of economic significance. We find that subsidizing foods via a reduced VAT rate was an efficient reform, as our simulated efficiency indicator suggests higher marginal welfare gains from tax cuts on foods than in case of non-

⁴ Papers from this literature closest to ours use the average elasticities estimated, commonly by QUAIDS, but not the fitted values (e.g. Savage, 2016).

⁵ A reduced rate of 10% applied to items with small budget shares, such as certain pharmaceutical and medical products, books and sheet music.

foods. We show further that the Slovak reform could have been fiscally neutral, welfare-improving and equitable at the same time, had the government increased the VAT rate for non-foods. Similar tax reform designs could be especially relevant to developing countries with largely uniform VAT schemes striving to improve both efficiency and equity at minimal or zero fiscal costs.

The rest of the paper is organized as follows. The next section is devoted to the theoretical framework. Section 3 describes our dataset. Section 4 deals with estimation issues. The following Section 5 presents simulation results and the final, Section 6 concludes.

2 Theoretical Framework

2.1 The Quadratic Almost Ideal Demand System

QUAIDS is based on AIDS and contains an additional quadratic log-expenditures term in budget share equations to provide sufficient flexibility for the shape of Engel curves (Banks et al., 1997).⁶ Such a functional form is consistent with empirical observations as it allows a luxury good to become a necessity (or vice versa) as income rises (falls). Omitting the indexation of households $h \in \{1, \dots, H\}$ and using the notation of Banks et al. (1997) we specify household preferences by the following indirect utility function:

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

where the term $[\ln m - \ln a(p)]/b(p)$ is the indirect utility function of the PIGLOG⁷ demand system, m is household income, and $a(p)$, $b(p)$ and $\lambda(p)$ are functions of the vector of prices p corresponding to N bundles of goods. The price index $\ln a(p)$ has the usual translog form:

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

⁶ Other commonly used demand systems modeling allocation of expenditures given a fixed budget constraint include the Linear Expenditure System (LES) (Stone, 1954), the Rotterdam model (Barten, 1964), and the Indirect Translog System (ITS) (Christensen et al., 1975).

⁷ Demand with expenditure shares that are linear in log total expenditure alone have been referred to as Price-Independent Generalised Logarithmic (PIGLOG) by Muellbauer (1976).

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

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

and $\lambda(p)$ is given by

$$\lambda(p) = \sum_{i=1}^N \lambda_i \ln p_i. \quad (4)$$

To fulfill the restrictions required by microeconomic theory and to reduce the number of parameters to be estimated, the following set of restrictions is imposed. The adding-up property of demand systems requires that:

$$\sum_{i=1}^N \alpha_i = 1; \quad \sum_{i=1}^N \beta_i = 0; \quad \sum_{i=1}^N \lambda_i = 0; \quad \sum_{i=1}^N \gamma_{ij} = 0 \quad \forall j. \quad (5)$$

Homogeneity of degree zero in prices and income requires that:

$$\sum_{i=1}^N \gamma_{ij} = 0 \quad \forall i. \quad (6)$$

The symmetry restriction of the Slutsky matrix is given by:

$$\gamma_{ij} = \gamma_{ji} \quad \forall i \neq j. \quad (7)$$

By applying Roy's identity to the indirect utility function in equation (1), the budget share equations of the QUAIDS are specified as:

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

where w_i is the share of commodity i in total consumption expenditure of a household.

Using the budget share equations one 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 first partially differentiating the budget share equation (8) with respect to income ($\ln m$) and price ($\ln p_j$) which yields:

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

and

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

Consequently, the budget elasticities can be computed as:

$$e_i = \mu_i/w_i + 1. \quad (11)$$

Whereas the uncompensated price elasticities can be computed as:

$$e_{ij}^u = \mu_{ij}/w_i - \delta_{ij}, \quad (12)$$

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

$$e_{ij}^c = e_{ij}^u + e_i w_j. \quad (13)$$

2.2 Marginal welfare gain of a VAT cut

Using the demand system (1) - (8) we can model VAT reforms as exogenous price changes and proceed to quantifying the associated demand response. This would allow us to simulate the impact of a tax cut on welfare and fiscal revenues at the household level. By aggregating the welfare and fiscal effects to the national level and taking their ratio we get the marginal welfare gain (MWG)⁸, which represents the gain in household welfare for a unit of fiscal revenues forgone by the government. Put differently, MWG serves as an efficiency measure of a VAT cut.

Let us assume a proportional VAT rate, t , which relates consumer prices, p , observed by households to producer prices, p^0 :

$$p = p^0(1 + t). \quad (14)$$

Next, suppose a uniform VAT scheme with a standard rate t^s applied to all commodities and a tax reform introducing a reduced rate t_i^r for commodity i , i.e. $0 \leq t_i^r \leq t^s$. Assuming a complete pass-through of VAT changes to prices, price p_i changes by the ratio:

$$\tau_i \equiv \frac{1+t_i^r}{1+t^s} < 1. \quad (15)$$

⁸ In case of VAT hikes, we could call the measure marginal welfare loss (MWL).

Let us denote tax revenues collected from household, h under the uniform VAT scheme as

$R^h(p) = \frac{t^s}{1+t^s} m^h$. Then post-reform revenues can be written as:

$$R^h(p_i \tau_i, p_{-i}) = \frac{t_i^r}{1+t_i^r} m^h w_i^h(p_i \tau_i, p_{-i}) + \frac{t^s}{1+t^s} m^h [1 - w_i^h(p_i \tau_i, p_{-i})], \quad (16)$$

where p_{-i} are prices of bundles other than i . Next, the change in tax revenues due to the reform can be expressed as:

$$\Delta R^h(p_i \tau_i, p_{-i}) = \left(\frac{t_i^r - t^s}{(1+t_i^r)(1+t^s)} \right) m^h w_i^h(p_i \tau_i, p_{-i}). \quad (17)$$

Note that ΔR_i^h is expected to be negative for a tax cut. Finally, the aggregate level revenue impact of a tax cut on bundle i is equal to the sum of individual impacts:

$$\Delta R_i = \sum_{h=1}^H \Delta R_i^h(p_i \tau_i, p_{-i}). \quad (18)$$

The impact of an exogenous price change on consumer welfare can be measured in several ways. We opt for the compensating variation (CV)⁹, which is a commonly used measure in the QUAIDS literature following Banks et al. (1997). As in case of government revenue, CV is measured in nominal monetary units, which makes the two variables comparable when analyzing the efficiency of tax reforms. CV is defined as the amount of cash transfer a household would need to receive *after* a price change to preserve its initial utility level, before the price change. Following the demand system (1) - (8), the compensating variation of a change in price p_i by τ_i , given initial utility level v_0^h , can be specified as:

$$CV_i^h(\tau_i) = e^h(p_i, p_{-i}, v_0^h) - e^h(p_i \tau_i, p_{-i}, v_0^h), \quad (19)$$

where the expenditure function, $e^h(p, v_0)$ can be expressed from (1) as:

$$e^h(p, v_0^h) = \exp \left(\ln a(p) + \frac{b(p) \ln v_0^h}{1 - \lambda(p) \ln v_0^h} \right) = m^h, \quad (20)$$

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

⁹ The concept was introduced by Hicks (1939) and was applied in the context of QUAIDS by Banks et al. (1996, 1997).

Alternatively, one could use the equivalent variation (EV) as the welfare measure, which is closely related to CV. The EV is defined as the amount of cash a household would be willing to pay *before* a price change to avoid the price change. Put differently, the difference in total expenditures corresponding to the envisaged and the initial utility levels is evaluated at the initial price vector:

$$EV_i^h(\tau_i) = m^h(p_i, p_{-i}, v_1^h(\tau_i)) - m^h(p_i, p_{-i}, v_0^h). \quad (21)$$

As we will demonstrate in the empirical part below, the two welfare measures yield very similar results in our case. So, in line with Banks et al. (1997), we will focus on CV as the baseline measure.¹⁰

Before aggregating the household level welfare impact (19) to the society level, let us introduce social welfare function U . In the related literature it is common to assume a social welfare function of the Bergson-Samuelson type, where U is a function of indirect utilities V^h of the population of households, $h = 1, \dots, H$:

$$U = U[V^1(m^1, p), \dots, V^H(m^H, p)]. \quad (22)$$

Let θ^h denote the social marginal utility of income of household h , i.e. the household's weight in social welfare. Welfare weight θ^h is treated as a parameter in this literature and is usually specified in terms of total expenditure per household m^h , relative to the same indicator for the poorest household in the population (sample) m^1 :

$$\theta^h = \left(\frac{m^1}{m^h}\right)^\varepsilon, \quad (23)$$

where ε is a non-negative parameter of inequality aversion. As we will show in Section 5.3 below, our results are not sensitive to equity considerations. So, in most of our empirical analysis we will assume a utilitarian social welfare function with zero inequality aversion

¹⁰ For a comparison of the empirical performance of different welfare measures see Banks et al. (1996).

($\varepsilon = 0$). The aggregate level welfare impact of a tax cut on commodity i can be expressed as the weighted sum of household level welfare impacts, where we plug CV_i^h to ΔV^h :

$$\Delta W_i = \sum_{h=1}^H \theta^h CV_i^h(p_i \tau_i, p_{-i}). \quad (24)$$

As the efficiency measure of commodity tax reforms, we introduce Marginal Welfare Gain (MWG). MWG at the aggregate level is defined as the ratio of ΔW_i and $-\Delta R_i$. This represents the gain in household welfare for a unit of fiscal revenue forgone by the government, given the rate of tax change τ_i :

$$MWG(\tau_i) = -\frac{\Delta W_i(\tau_i)}{\Delta R_i(\tau_i)}. \quad (25)$$

As an alternative to MWG, which is based on simulations from QUAIDS, one could consider first- and second-order approximations of ΔW and ΔR following the approaches of Ahmad and Stern (1984) and Ray (1999). Arguably, the advantage of the approximation approach is that estimates of uncompensated cross-price elasticities are sufficient statistics to perform the analysis, and computationally more intensive model simulations are not needed. The first-order approximations of the welfare and revenue impacts are derived by taking the first derivative of the respective expressions with respect to the tax rate t_i , denoted as $\partial U / \partial t_i$ and $\partial R / \partial t_i$ respectively. The second-order approximations extend the above expressions by the second term of the Taylor expansion, where the approximations are denoted as $\Delta U / \Delta t_i$ and $\Delta R / \Delta t_i$ respectively. Placing all the details of the derivation in Appendix A, we arrive at the following definitions of the two approximated MWG ratios:

$$MWG_i^{1st} \equiv -\frac{\partial U / \partial t_i}{\partial R / \partial t_i} \quad (26)$$

$$MWG_i^{2nd} \equiv -\frac{\Delta U / \Delta t_i}{\Delta R / \Delta t_i}. \quad (27)$$

3 Data

Our dataset comes from the Household Budget Survey (HBS) conducted by the Statistical Office of the Slovak Republic. Its main purpose is to collect information on the allocation of household expenditures and sources of income. The data contains information on socio-demographic indicators, such as gender, age, education, employment status for each household member. Households report the detailed structure of their monthly consumption as the information is recorded for the quarter in which the questionnaire was filled out. Each of the annual representative samples is composed of between 4500 and 6000 respondent households. Data available covers the 2006 - 2012 period but because the sample is selected randomly each year, a panel dataset cannot be constructed. Furthermore, in order to keep the model consistent with the simulations of VAT reforms due in a particular year, we use only the last year of data (2012) for estimation. This restriction leads to a sample of around 3500 households.

For the purposes of the analysis we aggregated the detailed expenditure information in the data into nine bundles: (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. The ‘Other non-foods’ bundle represents almost three quarters of the average household expenditure, therefore, we also run the set of analyses with this bundle split into two (sub) bundles – necessities (about 50%) and luxuries (about 25%); the results that we obtain are similar to the ones reported.^{11,12} Table B.1, Appendix B provides a detailed list of items in each bundle. The allocation of goods into the above bundles was mainly motivated by the recent VAT reform in Slovakia. The reform 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

¹¹ Further, we compared the cross-price elasticities of non-foods before and after the model extension. While all of them were statistically significant in the baseline case, the same holds only for about half of the elasticities of non-food necessities and luxuries.

¹² Note that unbalanced consumption shares across bundles is a standard feature of QUAIDS models. For example, the largest bundle in Banks et al. (1997) has about 50% share in total consumption (see Table 4, p. 536). While QUAIDS models with a detailed treatment of foods tend to include a large non-food bundle (e.g. a 91% share of non-foods in Abdulai, 2002, and a 73% share in Moro and Sckokai, 2000).

unchanged. The standard rate also did not change for bundles (7), (8), and (9). The government intended to focus the reform on basic, non-luxurious foods with the lowest possible share of imports, thereby supporting both low-income households and domestic producers. Apart from the above division of bundles based on the coverage of the VAT reform, the structure of our aggregated consumption bundles is similar to prior studies on food demand in Europe (e.g., Moro and Sckokai, 2000; Abdulai, 2002; Cupák et al., 2015).

Note that prices are not surveyed directly in the HBS. Implicit (unit) prices can be computed for a subset of consumption goods by dividing expenditures with physical quantities purchased; such information is available only for foods. Consequently, we can form price indices for the aggregated food bundles of the model as weighted geometric means using budget shares of the goods as weights (see e.g., Abdulai, 2002). This way we also obtain a considerable variation in household-specific prices. The variation in prices typically stems from quality differences, regional market conditions, and seasonal effects (Deaton, 1988). To adjust prices for such effects we follow the regression-based approach proposed by Cox and Wohlgemant (1986).¹³ We compute the price index for the consumption of non-food goods based on Eurostat's quarterly HICP indices¹⁴ in a breakdown by twelve COICOP¹⁵ categories. As in the case of foods, we use household-specific budget shares from the HBS to construct the price index for bundle (9)¹⁶ and in the next step we perform the above quality adjustment procedure.

¹³ In this approach deviations from the mean prices of the i -th food bundle are regressed on household-specific socio-economic characteristics such as income (and its quadratic term), household size (and its quadratic term), number of children, age, education, gender and working status of the household head to account for household demand preferences. To partly cope with the food price endogeneity issue in the demand system due to omitted supply-side factors, we also consider location and time dummies (region, season, trend, and rural vs. urban) to account for supply-side effects. Finally, the quality-adjusted prices of the i -th food category are computed by adding the residuals estimated from the price deviation regression back to the mean prices. Detailed estimates of the quality-adjustment regressions are available from the authors upon request.

¹⁴ Index values were equal to one for each commodity aggregate for the average of the base year 2005.

¹⁵ 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.

¹⁶ Our approach of using implicit prices from the HBS for foods and consumer price indexes in a commodity breakdown for non-foods is similar to the approach of Dybczak et al. (2014).

Definitions and summary statistics of the main variables (i.e., total expenditure, budget shares, and prices) entering the QUAIDS model are presented in Table B.2, Appendix B. As it follows from the table, the highest share of total household expenditure is allocated to non-food goods (and services) which is around 75%. Among food categories, households spend the most on unprocessed meat and other foods (4% each) and the least on other cereal and milk products (2% each).¹⁷ In Table B.2 we also provide definitions of demographic variables and their summary statistics which are used to account for heterogeneity in household preferences. The choice of demographic characteristics was based on data availability and the relevant academic literature on demand models.

4 QUAIDS estimation

We estimate QUAIDS for nine consumption bundles while controlling for demographic characteristics to capture the heterogeneity of household preferences. We use the last year (2012) of available data and our estimation sample consists of more than 3500 observations after eliminating outliers in household expenditure and price indices. Estimation was 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, Lecocq and Robin (2015) implement a computationally more attractive iterated linear least-squares estimator, which was originally proposed by Blundell and Robin (1999). An alternative estimator one could consider is the computationally more demanding non-linear seemingly unrelated regression (SUR), suggested by Poi (2012).

The presence of considerable cross-sectional heterogeneity in household-level data motivated the inclusion of socio-demographic effects in the specification. The literature offers two alternative implementation methods in this respect. The one we follow is the translating

¹⁷ It is worth mentioning that based on aggregate data, Slovak households allocate around 16% of their total expenditure to food while the European average is about 11%.

approach 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 introduces a non-linear effect. An alternative is the scaling technique proposed by Ray (1983) where socio-demographic heterogeneity is reflected in both the level and slope coefficients of budget share equations by rescaling the data.

When estimating demand models from detailed micro-data, no purchases of goods or services (zero expenditure) by households during the surveyed period may lead to the problem of censoring. Zero expenditures can arise for various reasons such as infrequency of purchases due to the short recording period of the survey, or never purchasing some goods or services, or no willingness for purchasing at given income or prices, i.e., a typical corner-solution problem. Estimating a demand system from data containing frequent zero expenditures would lead to biased parameter estimates (e.g., Barslund, 2011). To overcome this problem, different estimation procedures have been proposed and applied in the literature.¹⁸ These procedures have been frequently applied in empirical work on demand systems (e.g., Yen et al., 2002; García-Enríquez and Echevarría, 2016; 2018; Savage, 2016). However, in our case, zero expenditures almost vanish after the aggregation of items into broader categories.¹⁹ Therefore, we did not need to deal with the censoring issue in estimating the demand system.

Our demand system estimates are presented in Table B.3, Appendix B.²⁰ The estimated budget share equations are with good fit and statistical significance considering the relatively high values of R^2 and low p-values of the F-tests. Likewise, most of the estimated parameters of the QUAIDS model are statistically significant. Furthermore, parameters capturing the

¹⁸ See for example the two-step procedures of Heien and Wesseils (1990), Shonkwiler and Yen (1999) and Tauchmann (2010), or the Bayesian approach of Hasegawa et al. (2008).

¹⁹ The highest share of zero observations occurs in case of unprocessed meat (3.5%) and milk and butter (2%), while the share drops below 0.6% for the remaining seven bundles.

²⁰ The demand system was estimated under the homogeneity and symmetry restrictions defined in (6) and (7).

quadratic expenditure term (λ 's) as well as the demographic variables are highly statistically significant in most cases. This confirms the importance of flexible Engel curves and the demographic effects in estimating household behavioral responses to changes in income and prices. Finally, the estimation method of Lecocq and Robin (2015) allows for treating log expenditures as a potentially endogenous regressor, which may be an issue if unobserved heterogeneity in tastes is correlated with total expenditures. We followed Lecocq and Robin (2015) in using log income as an instrument in a three-stage estimation procedure and rejected the null hypothesis of exogeneity of log expenditures based on the test suggested.²¹

The sample average budget and price elasticities based on the estimated QUAIDS model are summarized in Table B.4, Appendix B. All elasticities are consistent with microeconomic theory and comparable to results from other European studies (e.g., Moro and Sckokai, 2000; Abdulai, 2002). Budget elasticities for all food bundles are smaller than one, suggesting that foods are necessities. The compensated own-price elasticities suggest that all goods in the model are price-inelastic only two bundles, processed meat and fruits and vegetables, are close to unit-elastic (around -0.9). Finally, majority of the compensated cross-price elasticities are positive which suggests that most food bundles are substitutes.

5 Simulating VAT cuts for foods

The goal of this section is to evaluate the recent VAT reform in Slovakia from the efficiency viewpoint. The reform reduced the standard rate of 20% to 10% for certain basic food categories such as bread, unprocessed meat, milk and butter which correspond to (some of) the consumption bundles in our model. First, we compute the welfare and fiscal revenue impacts of a tax cut for each bundle, one-by-one, and for multiple bundles, including a combination of bundles mimicking the actual reform (subsection 5.1). In this exercise we compare measures

²¹ In addition, the instrument was statistically significant in the first-stage regression of log expenditures on all exogenous variables.

based on QUAIDS simulation, Ahmad and Stern's (1984) first-order approximation and, for completeness, Ray's (1999) second-order approximation.²²

In the next subsection (5.2) we study the efficiency of tax cuts measured by MWG, again considering individual bundles and two multiple bundles. Our focus is on studying the bundle ranking order across our three measures. In the following two subsections (5.3 and 5.4) we check the sensitivity of our results to equity considerations (by expenditure deciles) and their robustness to a variety of (reduced) tax rates. In subsection (5.5) we estimate the welfare impacts of hypothetical revenue-neutral VAT reforms. And finally, in subsection (5.6) we carry out a sensitivity analysis with respect to the pass-through of the VAT change.

Simulations are performed in the following steps. We first estimate the demand system and save fitted budget shares for each bundle and household based on equation (8). The initial values of indirect utility are also estimated for each household according to equation (1). This is needed for calculating welfare effects. Further, we proceed with multiplying (household-level) prices of each bundle by $\tau = 1.1/1.2 \approx 0.917$ (a price cut of about 8.3%), to simulate the reduction in tax rate. Using the modified price data and the previously estimated parameters, we save the new fitted budget shares. In the final step we compute the simulated household-specific changes in welfare and tax revenues, ΔCV_i^h and $-\Delta R_i^h$ respectively.

5.1 VAT cuts for individual and multiple bundles

In Table 1 we present the welfare and fiscal revenue impacts of VAT cut from 20% down to 10% which translates into 8.3% price reductions for individual bundles. In terms of welfare impact, in the left panel of the table, we compare four measures: Compensating Variation (CV), Equivalent Variation (EV), both based on QUAIDS simulation, Ahmad and Stern's (1984) first-

²² Ahmad and Stern's (1984) approach is based on first-order approximations of the welfare and tax revenue effects. Ray (1999) argues that second-order approximations of the welfare and revenue effects could be more appropriate in the case of larger than infinitesimal (non-marginal) changes in the indirect tax scheme.

order approximation, and Ray's (1999) second-order approximation.²³ Our results for CV and EV are virtually identical,²⁴ which suggests that consumer preferences are quasi-linear. Therefore, in further analysis we can use either measure; we choose CV. The first- and second-order approximations, however, appear somewhat different from the simulation-based measures and from each other. In terms of fiscal revenue impact, in the right panel of Table 1, we find more notable differences across the simulation-based measure, and the first- and second-order approximations.

[Table 1 here]

As expected, considering prior studies (e.g., Banks et al., 1996), the approximated welfare measures are biased compared to the simulated ones. Looking at the results reported in the left panel of Table 1, the approximated welfare impacts are neither systematically lower or higher than the simulated impacts, nor are they markedly different. In contrast, the approximated fiscal cost figures (the right panel of Table 1) tend to significantly overstate the fiscal effect compared to the simulated values in case of foods, while the approximations underestimate the fiscal effect for the largest bundle of non-foods. At the same time, the first-order approximated welfare and fiscal impacts are systematically smaller in absolute value than the second-order ones, in line with the theoretical predictions.

We repeat the calculations for two multiple bundles - the one mimicking the actual tax reform in Slovakia (comprising bundles 1, 3, and 5) and for all food bundles combined. The relationships between the different measures of welfare and fiscal revenue impacts remain similar as in the case of individual bundles.

Overall, the estimated costs of VAT reforms appear quite small when considering individual food bundles, i.e. on average a few euros per household and month. In contrast, a tax

²³ In case of the approximate measures, we multiply the marginal effects by the tax change ($\partial\tau = 0.1$), assume zero inequality aversion ($\varepsilon = 0$), and use budget shares fitted from the demand system.

²⁴ García-Enríquez and Echevarría (2016, 2018) came to a similar finding.

cut on the largest, non-food bundle appears the costliest from the fiscal point of view. This amounts to about 50 euros from the monthly budget of an average household.

5.2 Ranking bundles based on MWG

In Table 2 we consider three versions of MWG, the ratios of QUAIDS-simulated welfare and fiscal impacts and the first- and second-order approximated impacts. As evident from the table, the simulated versus the approximated MWGs produce completely different rankings of bundles as the first- and second-order approximations imply the same ranking.²⁵ As one would expect, the values of approximated MWG are smaller than the simulated version, as for the denominator we found evidence of a systematic upward bias in most cases (see Section 5.1). Further, the upward bias in the approximated fiscal costs for food bundles and the downward bias for non-foods seems to contribute to the highest ranking of non-foods according to the first- and second-order approximations.

[Table 2 here]

Further, the simulated values of MWG for food bundles and their combinations are consistently larger than the value for non-foods. This implies that tax cuts for foods are more efficient than for non-foods and that the actual VAT reform in Slovakia (comprising bundles 1, 3, and 5) was efficient. The same is also true for a hypothetical VAT reduction for all foods (the last line in Table 2). This latter option has an advantage in terms of administrative and implementation costs because public authorities would not have to differentiate between food bundles (categories), taxed at differential rates. When considering the rankings based on the approximated efficiency measures, however, we observe the opposite relative efficiency of foods compared to non-foods.

5.3 Sensitivity analysis - marginal welfare gains by expenditure deciles

²⁵ We tested the difference between the rankings using Kendall's non-parametric rank correlation test. The null hypothesis of independence cannot be rejected for the simulation-based versus the approximation-based pairs of rankings.

Apart from efficiency, another relevant economic question relates to the distributional impact of VAT reforms. This is to ask whether welfare and fiscal impacts are different across expenditure deciles. We show in Figures 1 and 2 the distributions of welfare and fiscal impacts measured in monetary terms and as a proportion of total expenditure. As can be seen from the figures, both the welfare and fiscal impacts are increasing in total expenditure (income) for the food bundles (subfigures in the left panels). However, if expressed as a percentage of total expenditure, both impacts are slightly decreasing in absolute values (subfigures in the right panels). The latter tendency is related to the fact that food bundles are necessities and their budget shares are shrinking for higher expenditure or income. In contrast, for the non-foods bundle, the share in total expenditure is rising for higher deciles (see Figure 2) which can be explained by the non-foods aggregate behaving as a luxury good.

[Figure 1 here]

[Figure 2 here]

Despite increasing welfare and fiscal impacts for higher deciles, the ratio of the two (MWG) is nearly constant for most bundles over a large part of the distribution (except for the 10th decile) as evident from Figure 3. However, the decreased MWG for other cereals and unprocessed meat, as well as the drop in MWG for some additional food bundles in the 10th expenditure decile are notable exceptions. Put differently, MWGs and their relative ranking across bundles are relatively stable from the bottom to the one but last expenditure decile. This suggests that equity considerations, assigning different social weights to households with different expenditure levels are not likely to change the efficiency ranking of bundles significantly.

[Figure 3 here]

5.4 Sensitivity analysis - marginal welfare gains by tax rates

Throughout our empirical analysis we assumed a fixed VAT cut, from the base rate of 20% to a reduced rate of 10%. This was motivated by the case of the actual VAT reform in Slovakia. Given that the QUAIDS model is non-linear, one may ask whether our results are robust to considering different reduced rates. Hence, we computed the MWG for each bundle for a range of alternative tax rates. Specifically, our simulations covered VAT rates ranging from 0% to 27%, by a step of 0.5 percentage points.²⁶ This means we consider both tax cuts and hikes for an individual bundle. The upper bound of the range, 27% is the highest currently observed VAT rate in the EU.

MWGs by levels of tax rate are depicted in Figure 4. The results suggest that the efficiency ranking of most bundles is relatively stable for the range of tax rates considered. All MWG curves are linear and are slightly, and monotonically increasing in tax rate.

[Figure 4 here]

5.5 Welfare gains from revenue-neutral reforms

Using the results above, we can compare the efficiency of tax cuts on various food bundles vis-a-vis the reference bundle, non-foods. Our motivation is to identify potential revenue-neutral welfare-improving VAT reforms. Such reforms cut the VAT on goods associated with a high MWG and simultaneously increase the VAT on goods with a low MWG, while the fiscal impact is kept zero. In our setup, a minor VAT hike on the large bundle of non-foods can provide enough fiscal revenues to finance more significant tax cuts on any of the food bundles. Therefore, this subsection is devoted to simulating cuts on different food bundles combined with hikes on non-foods.

When simulating revenue-neutral tax reforms we introduce exogenous price changes in the model. The changes reflect a reduced rate of 0% for one or more food bundles and an increased rate for the non-foods bundle. As for the remainder of the food basket, the standard

²⁶ Note that the base rate of 20% is excluded because MWG is not defined at this point.

rate of 20% is maintained. We use grid search with gradual 0.01 percentage points increases in VAT to find the increased rate on non-foods which would minimize the overall fiscal impact (ΔR) of the reforms.²⁷ On the top of QUAIDS simulations, the algorithm to find the revenue-neutral tax scheme is also repeated using the expressions for the approximated fiscal effects. The resulting tax schemes for each reform are reported in Table 3. Once the respective revenue-neutral tax scheme is identified, we estimate the welfare impact as before (using CV or any approximate measure).

[Table 3 here]

Results of the welfare impacts are presented in Tables 4 and 5 for each of the three welfare measures we considered previously. Table 4 contains results for ten VAT reform scenarios and two levels of the inequality aversion parameter, which also provide for robustness analysis. Rows list the eight food bundles and their two combinations (multiple bundles). Each column displays the sample weighted average welfare impacts expressed in euros per month, per household, where we use two values (1 and 5) for the inequality aversion parameter within welfare weights (23). Table 5 reports the ranks of policies for the same set of scenarios.

Our main finding is that the QUAIDS-simulated measure produces positive revenue-neutral welfare impacts while the other two approximate measures generate predominantly negative effects. We argue that this finding taken together with the magnitude and ranking of the MWG indicator suggests that our simulated measure performs better in informing the design of welfare improving revenue-neutral VAT reforms in Slovakia.

Our findings further suggest that the revenue-neutral welfare effects are positive, but rather small. When considering the actual Slovak VAT reform, which combined bundles 1, 3, and 5, we can see that it could be implemented as a revenue-neutral welfare improvement.

²⁷ This is done by repeatedly saving fitted budget shares w_i from (8) under a modified set of prices (VAT scheme) and keeping the estimated parameters of QUAIDS fixed. The impact of changed prices on budget revenues ΔR is calculated in each step via (18) and (19). The increased rate on non-foods corresponding to the smallest $|\Delta R|$ is recorded as the final estimate.

Overall, the level of inequality aversion affects the magnitude and relative ordering of the welfare effects under the revenue-neutrality constraint. Notice further that the welfare impacts are larger for higher inequality aversion, which implies that the suggested revenue-neutral reforms would also improve equity. In other words, we found no evidence of an equity-efficiency trade-off.

[Table 4 here]

[Table 5 here]

We also explore graphically the distributional impacts of the above revenue-neutral reform scenarios. As we can see from Figures 5, 6, and 7, the welfare impacts are slightly positive and slightly decreasing over the first eight expenditure deciles. While the impacts sink quite sharply below zero for the last two deciles. This means the hypothetical reforms would improve the overall efficiency of a uniform indirect tax scheme. At the same time, we observe redistribution of welfare from the top 20% of spenders to the relatively worse off households. In other words, the graphical results reinforce the evidence against the equity-efficiency trade-off for the tax reforms considered.

For comparison, we added the first- and second-order approximate welfare impacts in Figures 5, 6 and 7, which lie systematically below the QUAIDS-based estimates and take negative values in most cases. At the same time, one must keep in mind that the approximated revenue-neutral welfare impacts assume significantly higher VAT rates for non-foods than the QUAIDS simulation does (see Table 3).

[Figure 5 here]

[Figure 6 here]

[Figure 7 here]

5.6 Sensitivity analysis – the pass-through of VAT changes to prices

In equation (15) and the whole empirical analysis so far, we assumed a complete pass-through of VAT changes to prices. However, according to recent estimates for the euro area (see Benedek et al., 2020),²⁸ the VAT pass-through may not be complete. So, we check the sensitivity of our findings to this assumption.

In order to estimate the pass-through rate φ_i for food price i , we follow the approach of García-Enríquez and Echevarría (2018) based on the simple formula:

$$\varphi_i \equiv \frac{(p_i^1 - p_i^0)/p_i^0}{(t_i^1 - t_i^0)/(1 + t_i^0)}, \quad (28)$$

where p_i^0 and p_i^1 denote prices before and after the VAT change, while t_i^0 and t_i^1 are the corresponding VAT rates. Regarding the Slovak CPI data in a commodity breakdown, sufficiently detailed indexes are only available from December 2015, i.e. a month before the Slovak VAT reform took effect. Therefore, we computed the consumption-weighted average prices in December 2015 and February 2016 for the food items involved in the tax reform. The resulting pass-through figure amounts to 78%, which represents the contemporaneous effect or the lower bound of the overall pass-through that would be observed over a longer period before and after the VAT reform. In the sensitivity analysis below, we assumed the above estimate for all foods.

In the next step we, first, recalculated the (revenue non-neutral) welfare and revenue impacts of a VAT cut from 20% to 10% using the QUAIDS model and the above pass-through parameters. An incomplete pass-through led to lower welfare impacts, which were roughly proportional to the degree of pass-through. In contrast, revenue impacts changed only very slightly. The latter result follows from the fact that the tax base (nominal expenditures) is not altered too much for different degrees of pass-through, as the price- and quantity effects largely

²⁸ The authors use monthly panel data of about 70 commodity prices and their associated VAT rates in 17 euro area countries for the period 1999-2013.

cancelled each other out. We do not report the above results in detail, but they are available from the authors on request.

Next, we re-run the simulations of hypothetical revenue-neutral reforms with incomplete pass-through for foods and non-foods. Regarding non-foods, there were no relevant VAT changes observed in Slovakia, so we use the estimate of Benedek et al. (2020) for standard rates (column 1 of Table 3, p.902). This amounts to 79%, i.e., close to the value we calculated for foods. To illustrate the sensitivity of the results, we considered two more cases when the pass-through was complete either for foods or for non-foods and incomplete for the rest of the bundles. We found some sensitivity of the welfare impacts to the pass-through assumption, but only in case of a reform introducing a zero rate for all foods. As can be seen in the figure below, the welfare impacts are larger (smaller) when the pass-through for foods is higher (lower) than for non-foods. The rest of the revenue-neutral reforms we studied in the previous section were only mildly sensitive to the pass-through assumptions in this exercise; these results are available on request.

[Figure 8 here]

6 Conclusions

We estimate a QUAIDS model for eight food bundles and a non-food aggregate with Slovak household-level data. Using the model, we simulate household-level demand responses to the recent Slovak VAT reform and its hypothetical alternatives. The model enables us to consistently quantify the impacts on household welfare and fiscal revenues. We use the ratio of welfare and fiscal-revenue impacts as an efficiency indicator, which we refer to as the marginal welfare gain. Based on the indicator we can consistently rank the individual consumption bundles or their combinations. Overall, we find that the actual VAT reform in Slovakia which reduced the standard rate of 20% to 10% for certain basic food categories such as bread,

unprocessed meat, and milk and butter is efficient, as our efficiency indicator suggests higher marginal welfare gains from tax cuts on foods than in case of non-foods.

The paper contributes to the literature in two respects. First, to the best of our knowledge, we are the first to use simulation results instead of the standard approximate measures for constructing the efficiency indicator, used in the evaluation of tax reforms. We show that the approximation approach, commonly used in the literature, leads to a biased ranking of alternative policies compared to the simulation approach. The disagreement in ranking results mainly from the fact that the approximate welfare and fiscal impacts are based on average price elasticities as predictors of demand responses, which are less precise than model simulations. This imprecision is aggravated especially in case of a non-linear demand and non-marginal tax reforms and price changes.

Second, the analysis of marginal welfare gains 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 estimated impacts of hypothetical reforms that could increase the welfare of households at zero fiscal costs, as the case of Slovakia demonstrates. The reforms we examine depart from a uniform VAT scheme, as we apply reduced rates on foods while increasing the rate on the non-food aggregate. We find that such schemes can improve welfare in the case of food bundles. Welfare improvements are confirmed even for a reduced rate applied on all food bundles financed by an increased rate on the non-food aggregate. We conjecture that the possibility of welfare-improving departures from a uniform VAT scheme is a result of preference heterogeneity. However, potential revenue-neutral welfare gains are rather small in Slovakia. In addition to those welfare improvements by revenue-neutral tax reforms, we find redistributive effects channeling resources from households in the top two expenditure deciles to lower ranked households. In other words, our hypothetical reforms do not face an equity-efficiency trade-off.

Regarding the general policy implications of our results, we conclude that using a demand model to rank commodities according to their marginal welfare gains can be helpful for designing efficient VAT reforms. Further, ranking can provide guidance for identifying potential revenue-neutral, welfare-improving tax reforms. We recommend relying on simulation results in estimating the welfare and fiscal-revenue impacts of reform alternatives rather than utilizing approximate measures of the impacts. Finally, our results imply that revenue-neutral tax schemes that subsidize necessities financed by taxing luxuries can improve both equity and efficiency. However, further research is needed to verify whether similar results could be established for other countries or for alternative sets of commodity groups. Tax reform designs studied in the present paper could be especially relevant to developing countries with largely uniform VAT schemes striving to improve both efficiency and equity at minimal or zero fiscal costs.

Supplementary Material

Supplementary material is available online at the OUP website. This material consists of an online appendix and the replication file for this paper's analysis. The paper uses household-level microdata data from the Household Budget Survey (HBS) conducted by the Statistical Office of the Slovak Republic (SOSR). The HBS data can be accessed via an application to the SOSR.

Funding

The authors acknowledge the financial support from the Slovak Research and Development Agency [APVV-16-0321].

Acknowledgements

We would like to thank the participants in the National Bank of Slovakia research seminar in Bratislava (2017) and in the Slovak Economic Association conference in Bratislava (2018) for their useful suggestions and comments. For helpful comments we are also particularly grateful

to Martin Šuster, Pavel Gertler, and Matúš Senaj. Most of all we would like to thank the two anonymous referees and the editor Francis Teal for their very useful comments and suggestions, which significantly improved the paper. The views and results presented in this paper are those of the authors and do not necessarily represent the official opinions of their affiliation institutions.

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Tables and figures to be included in the main text

Table 1: Welfare and revenue effects of a VAT cut from 20% to 10%

		Welfare impact				Revenue impact		
		QUAIDS CV	QUAIDS EV	First-order approx.	Second-order approx.	QUAIDS	First-order approx.	Second-order approx.
1	Bread	2.00	2.00	1.95	2.00	-1.72	-3.25	-3.36
2	Other cereals	1.20	1.20	1.21	1.23	-1.04	-1.65	-1.70
3	Unprocessed meat	2.78	2.79	2.81	2.85	-2.39	-4.23	-4.30
4	Processed meat	2.12	2.13	2.04	2.12	-1.85	-3.46	-3.62
5	Milk and butter	1.02	1.02	0.99	1.03	-0.89	-1.23	-1.29
6	Other dairy	2.22	2.22	2.14	2.22	-1.92	-2.16	-2.31
7	Fruits and vegetables	2.21	2.21	2.14	2.22	-1.94	-2.49	-2.65
8	Other foods	2.64	2.65	2.58	2.67	-2.30	-3.36	-3.53
9	Other non-foods	51.93	56.06	51.42	53.66	-46.94	-42.45	-46.92
1,3,5	Bread, Unpr. meat, Milk	5.82	5.84	5.76	5.76	-5.02	-8.70	-8.94
1-8	All foods	16.12	16.33	15.87	15.87	-14.06	-21.80	-22.75

Note: Sample average euros per household per month.

Source: Authors' calculations using Slovak HBS data.

Table 2: Ranking of bundles based on MWG

		MWG			Ranks		
		QUAIDS CV	First-order approx.	Second-order approx.	QUAIDS CV	First-order approx.	Second-order approx.
1	Bread	1.165	0.601	0.597	2	8	8
2	Other cereals	1.154	0.731	0.724	4	6	6
3	Unprocessed meat	1.166	0.666	0.663	1	7	7
4	Processed meat	1.150	0.590	0.586	6	9	9
5	Milk and butter	1.152	0.810	0.794	5	4	4
6	Other dairy	1.157	0.994	0.962	3	2	2
7	Fruits and vegetables	1.140	0.861	0.838	8	3	3
8	Other foods	1.148	0.769	0.756	7	5	5
9	Other non-foods	1.106	1.212	1.144	9	1	1
1,3,5	Bread, Unpr. meat, Milk	1.157	0.662	0.644	1	2	2
1-8	All foods	1.147	0.728	0.697	2	1	1

Source: Authors' calculations using Slovak HBS data.

Table 3: VAT rates considered in revenue-neutral reforms

		Reduced rate (foods in row)	Standard rate (the rest of foods)	Increased rate for non-foods		
				QUAIDS	First-order approx.	Second-order approx.
1	Bread	0%	20%	20.86%	21.53%	21.69%
2	Other cereals	0%	20%	20.51%	20.78%	20.85%
3	Unprocessed meat	0%	20%	21.14%	21.99%	22.14%
4	Processed meat	0%	20%	20.95%	21.63%	21.85%
5	Milk and butter	0%	20%	20.45%	20.58%	20.66%
6	Other dairy	0%	20%	20.97%	21.02%	21.19%
7	Fruits and vegetables	0%	20%	21.00%	21.17%	21.37%
8	Other foods	0%	20%	21.17%	21.58%	21.81%
1,3,5	Bread, Unpr. meat, Milk	0%	20%	22.51%	24.10%	24.64%
1-8	All foods	0%	-	27.42%	30.27%	33.25%

Note: The pre-reform tax scheme is a uniform VAT rate at 20% for all items.

Source: Authors' calculations using Slovak HBS data.

Table 4: Welfare impacts of revenue-neutral reforms

Welfare measures		QUAIDS simulation		First-order approx.		Second-order approx.	
Inequality aversion:		$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 1$	$\varepsilon = 5$
1	Bread	0.16	0.72	-2.72	-0.39	-3.12	-0.50
2	Other cereals	0.10	0.37	-1.06	-0.14	-1.25	-0.19
3	Unprocessed meat	0.39	0.82	-3.11	-0.63	-3.50	-0.76
4	Processed meat	0.01	0.48	-3.00	-0.66	-3.54	-0.81
5	Milk and butter	0.05	0.26	-0.61	-0.02	-0.81	-0.08
6	Other dairy	0.07	0.53	-0.40	0.30	-0.80	0.19
7	Fruits and vegetables	0.06	0.58	-0.97	0.10	-1.44	-0.04
8	Other foods	0.13	0.78	-1.85	-0.06	-2.42	-0.23
1,3,5	Bread, Unpr. meat, Milk	0.46	1.75	-6.44	-1.04	-7.79	-1.47
1-8	All foods	0.19	2.03	-13.70	-1.48	-20.87	-3.86

Note: Weighted average euros per household per month. Weights are based on inequality aversion, see equation (23). VAT is cut to 0% for foods in the row, the standard rate of 20% applies to the rest of foods and non-foods are taxed by an increased rate (see Table 3).

Source: Authors' calculations using Slovak HBS data.

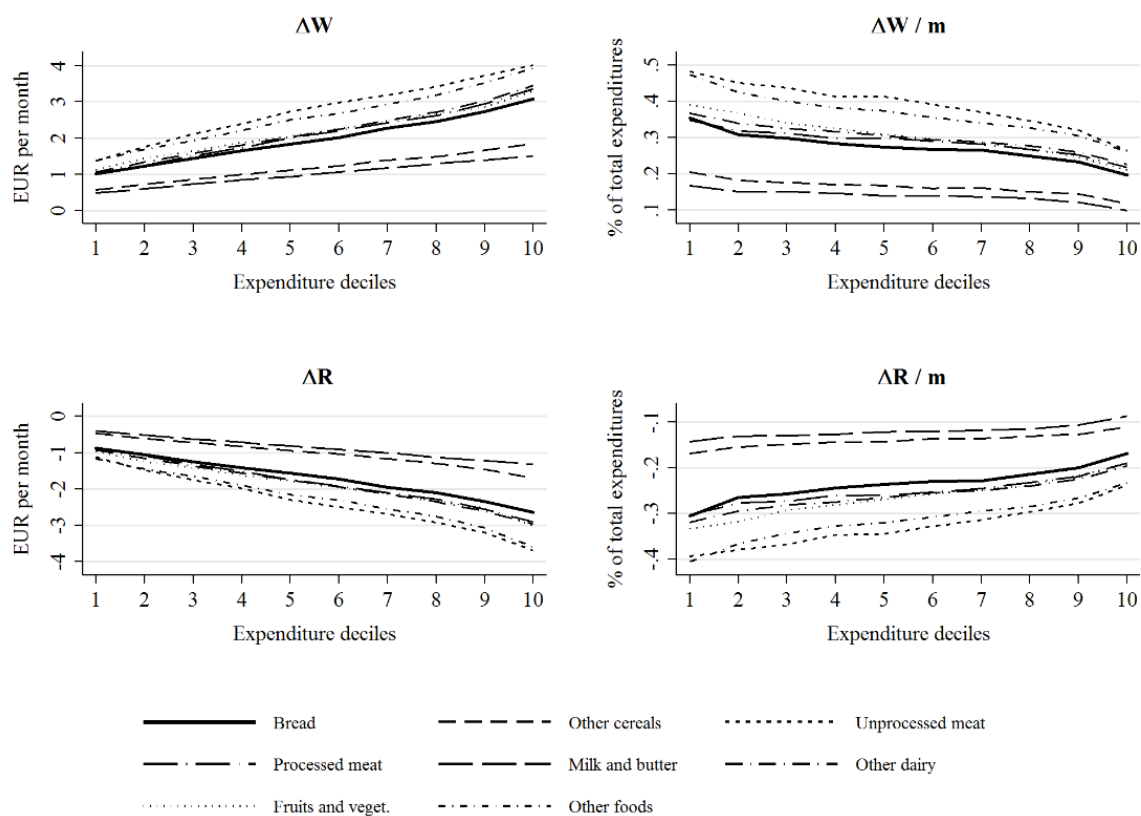
Table 5: Welfare-based ranks of revenue-neutral reforms

Welfare measures		QUAIDS simulation		First-order approx.		Second-order approx.	
Inequality aversion:		$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 1$	$\varepsilon = 5$
1	Bread	2	3	6	6	6	6
2	Other cereals	4	7	4	5	3	4
3	Unprocessed meat	1	1	8	7	7	7
4	Processed meat	8	6	7	8	8	8
5	Milk and butter	7	8	2	3	2	3
6	Other dairy	5	5	1	1	1	1
7	Fruits and vegetables	6	4	3	2	4	2
8	Other foods	3	2	5	4	5	5
1,3,5	Bread, Unpr. meat, Milk	1	2	1	1	1	1
1-8	All foods	2	1	2	2	2	2

Note: The differences between simulation-based and approximation-based pairs of rankings are statistically significant according to Kendall's non-parametric rank correlation test.

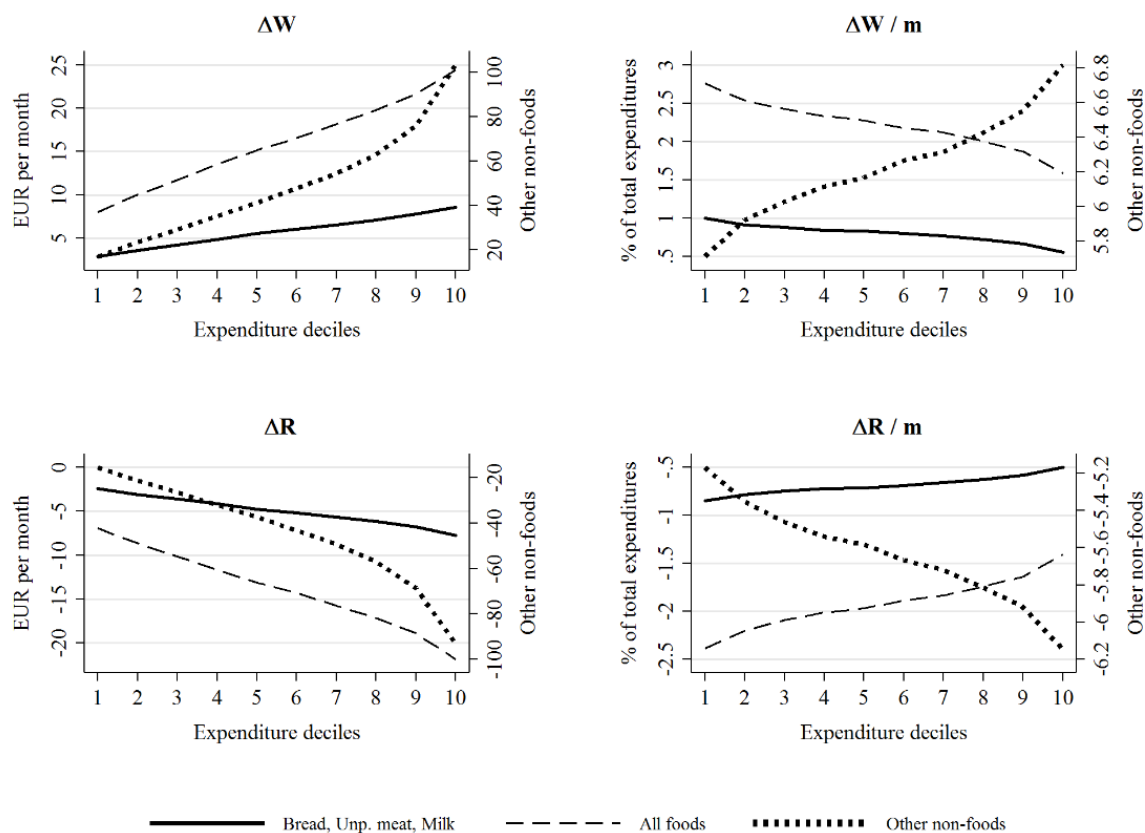
Source: Authors' calculations using Slovak HBS data.

Figure 1: Welfare and revenue impacts of a VAT cut from 20% to 10% on individual bundles



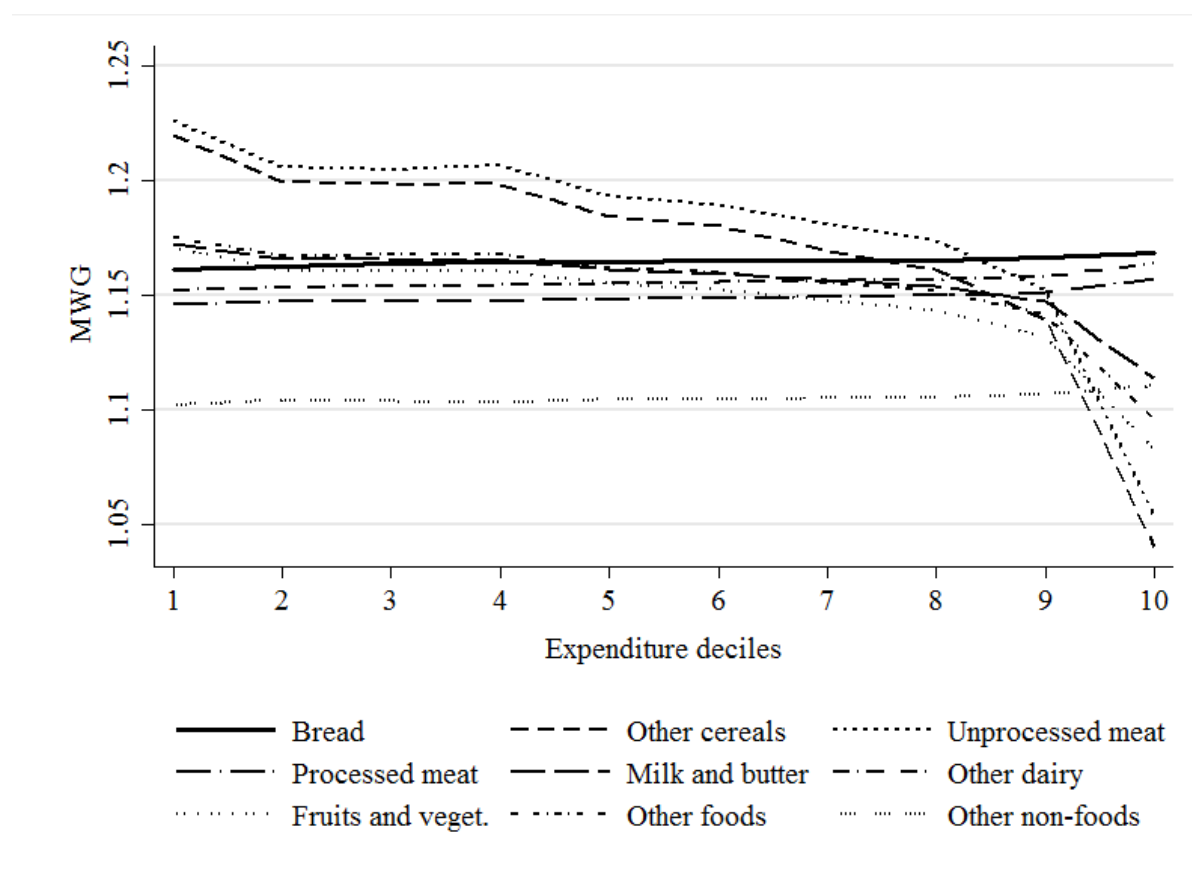
Note: Median values of each variable in each decile.
Source: Authors' calculations using Slovak HBS data.

Figure 2: Welfare and revenue impacts of a VAT cut from 20% to 10% on multiple bundles and other non-foods



Note: Median values of each variable in each decile.
Source: Authors' calculations using Slovak HBS data.

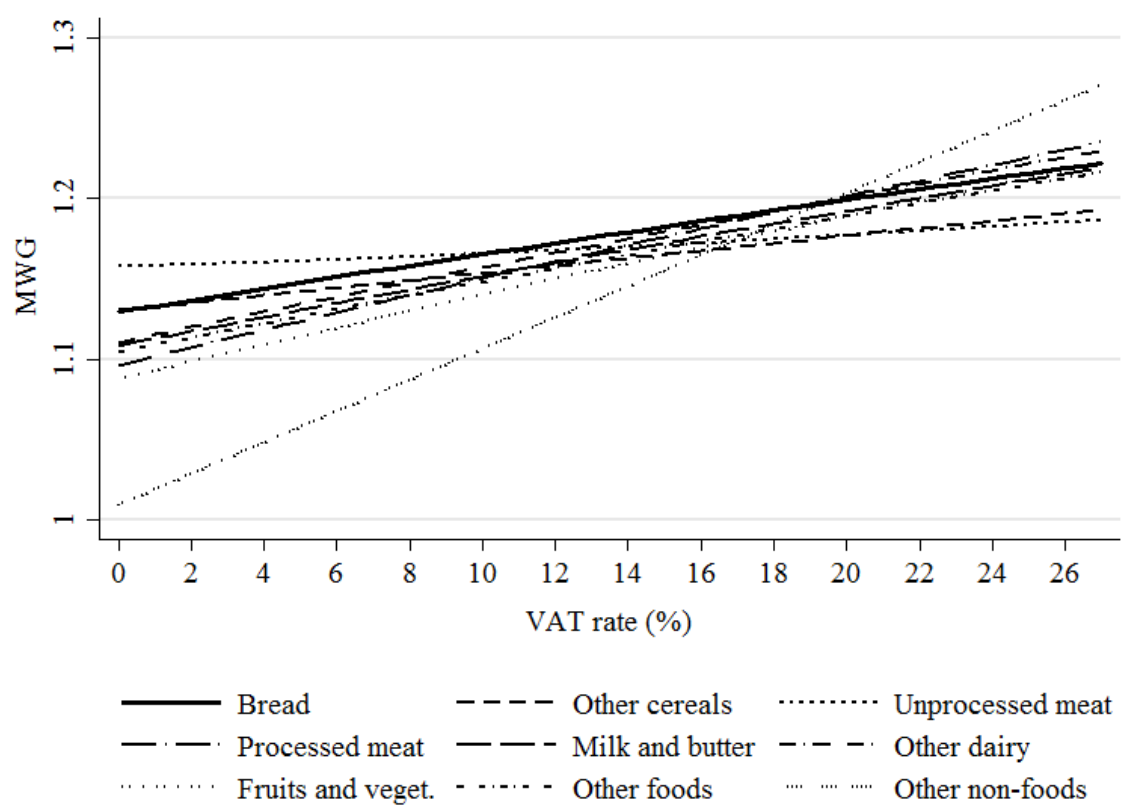
Figure 3: Marginal welfare gains by expenditure deciles



Note: The MWG ratios are computed from sums of individual welfare and revenue effects in each expenditure decile.

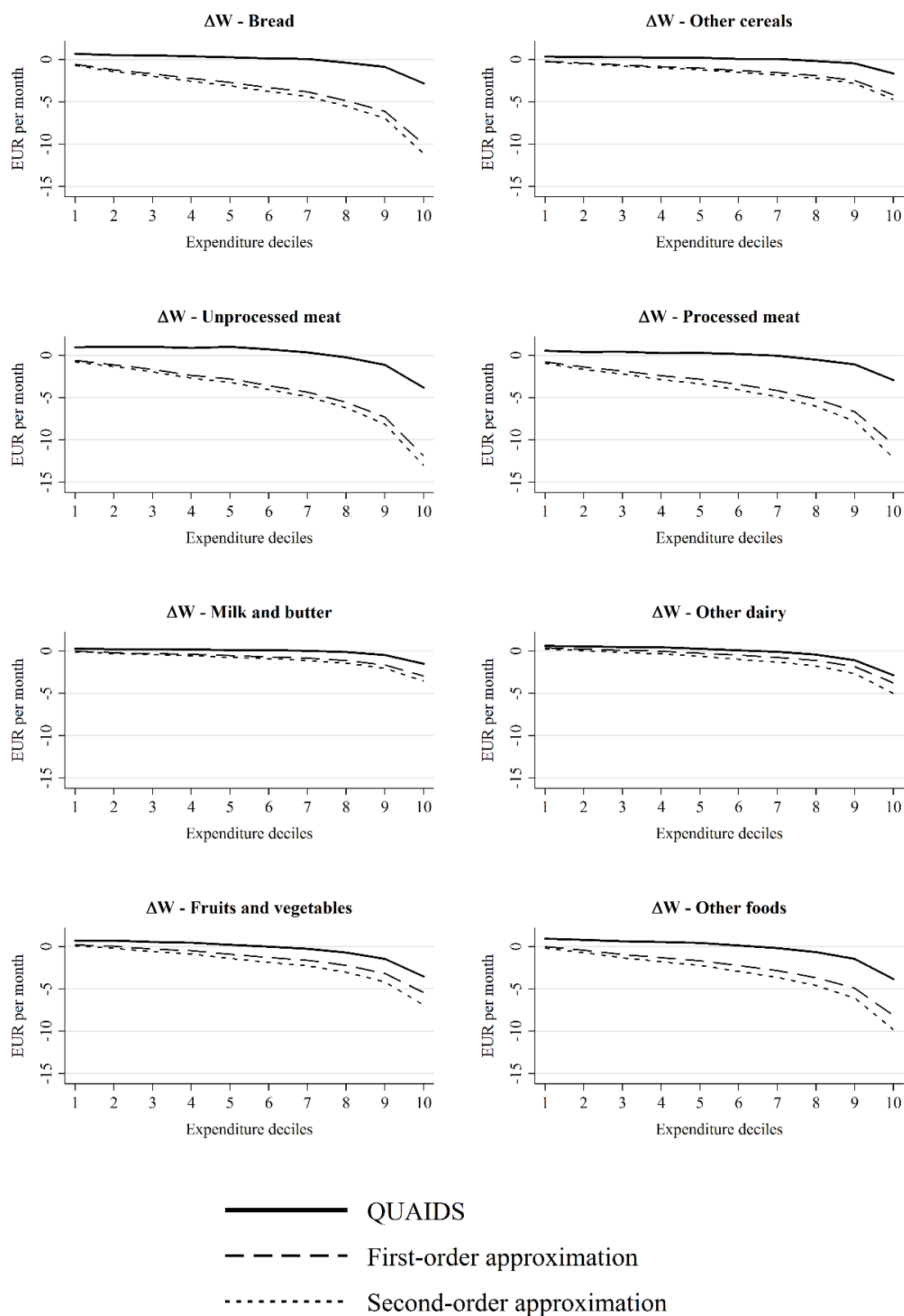
Source: Authors' calculations using Slovak HBS data.

Figure 4: Marginal welfare gains by VAT rates



Source: Authors' calculations using Slovak HBS data.

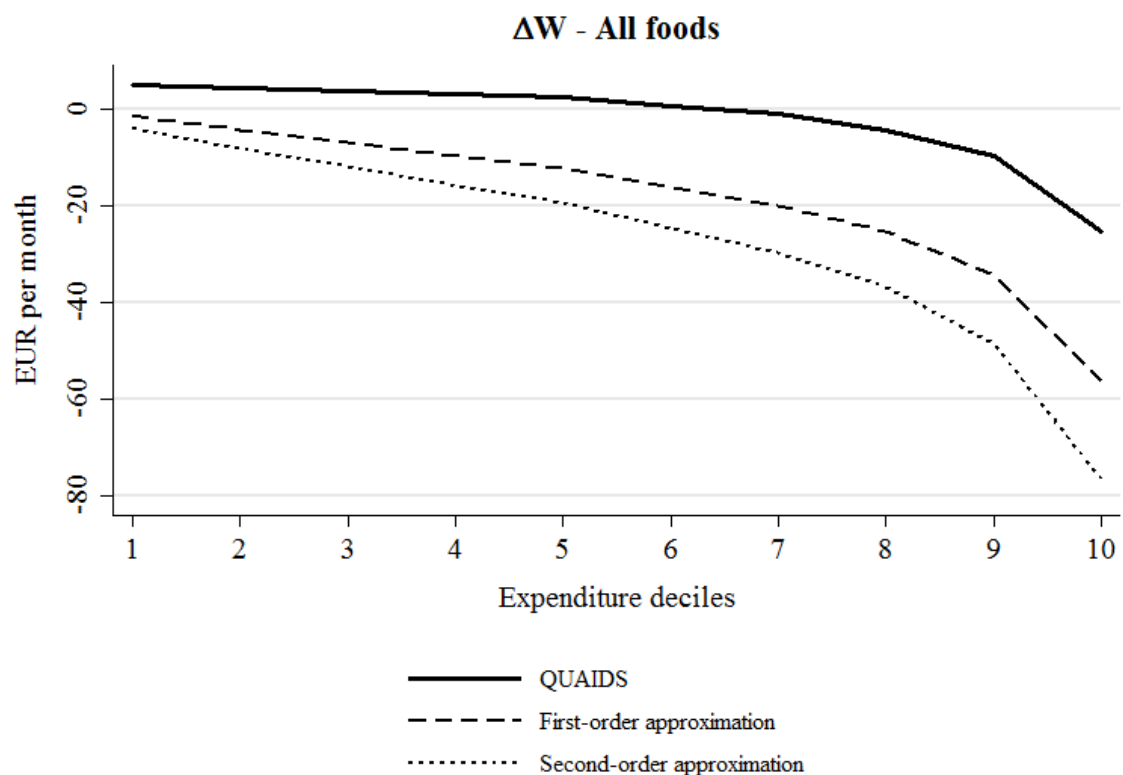
Figure 5: Revenue-neutral welfare impacts (VAT cut from 20% to 0%, individual bundles)



Note: Median values for each decile.

Source: Authors' calculations using Slovak HBS data.

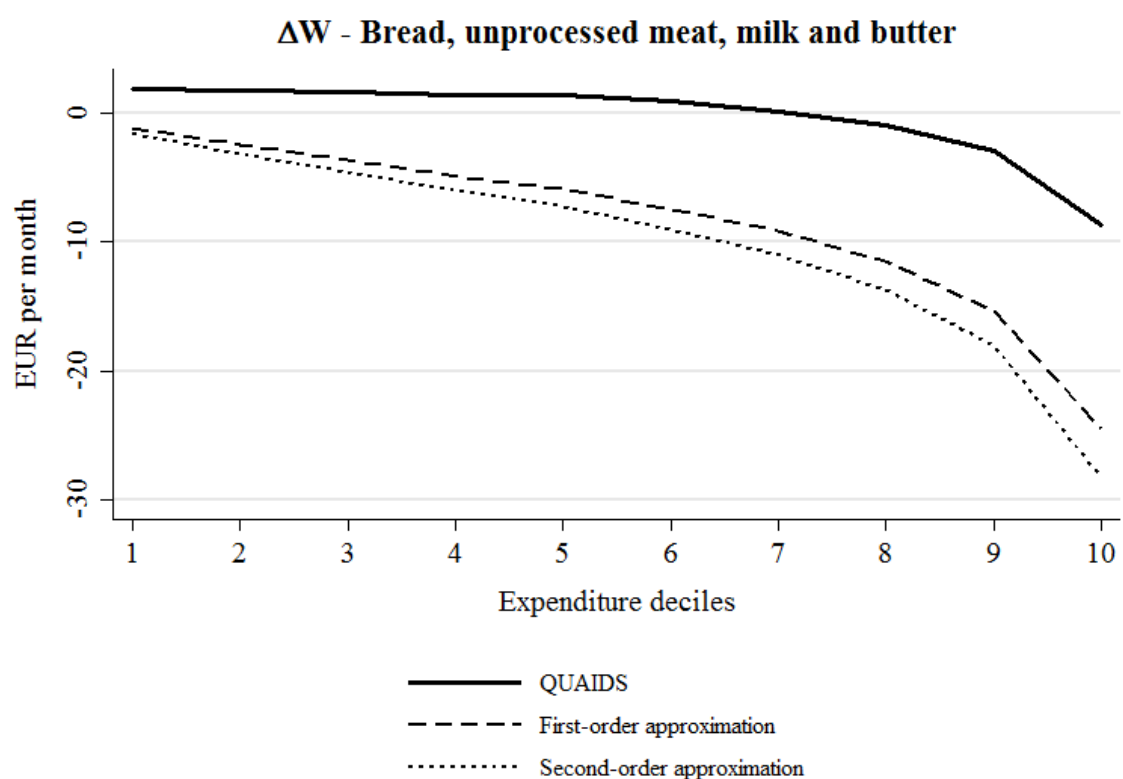
Figure 6: Revenue-neutral welfare impacts (VAT cut from 20% to 0%, multiple bundles)



Note: Median values for each decile.

Source: Authors' calculations using Slovak HBS data.

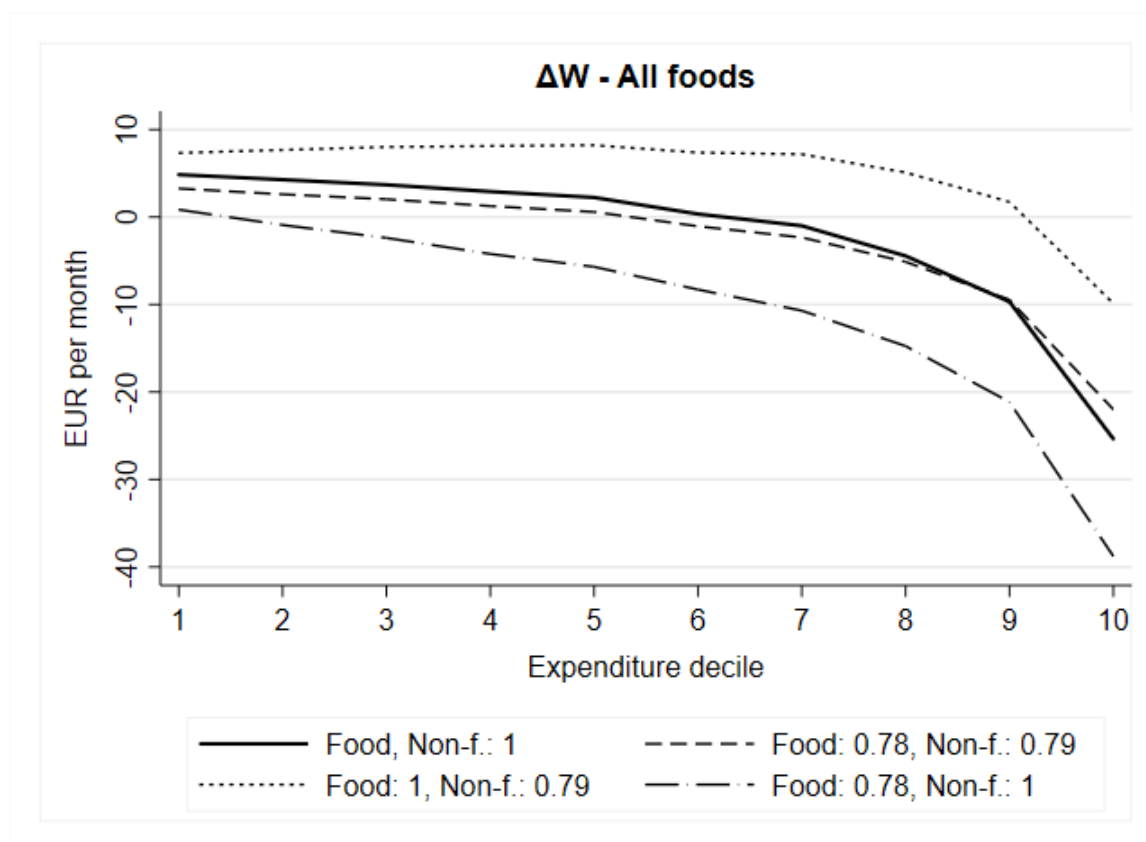
Figure 7: Revenue-neutral welfare impacts (VAT cut from 20% to 0%, multiple bundles)



Note: Median values for each decile.

Source: Authors' calculations using Slovak HBS data.

Figure 8: Revenue-neutral welfare impacts and VAT pass-through (VAT cut from 20% to 0%, multiple bundles)



Note: Median values for each decile.

Source: Authors' calculations using Slovak HBS data.