Supply Constraints in a Heterogenous Agents Household Demand Model:

A Method for Assessing the Direct Impact of the COVID Lockdown

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Abstract: The COVID pandemic has led to worldwide short-term lockdowns that mostly affected services with personal contact. In economic terms, the lockdown represents a supply shock that simultaneously leads to a demand restriction. The direct effect of the supply constraint is a change in both the structure and the level of consumption. The critical issue for the level effect is the rebound of total consumption, when the lockdown is over. In a model with heterogenous agents that exhibit different consumption structures and different behavior at the aggregate level ('permanent income hypothesis' consumers vs. liquidity constrained consumers), the rebound is not complete within the same period, but only over t and $t + 1$. In the first year, negative aggregate consumption effects are observed. The supply constraints act at the level of single goods and induce large changes in the level of consumption in both directions. This aspect of structural adjustment that occurs without aggregate changes, is an underrepresented issue in the current policy debate. This paper presents a method of consistent implementation of supply constraints via exogenous variables in a nested demand system and of calculating the direct consumption impact across household income groups.

Key words: heterogenous agents, consumption demand system, supply constraints

JEL codes: D11, D12, D31

Introduction

The macroeconomic literature of the last decades has emphasized the importance of dealing with heterogenous agents (for one of many recent examples, see: Ravn and Sterk, 2020). Pure macroeconomic models have – for example - introduced different household types in terms of their reaction in consumption to transitory income shocks. That led to the distinction between 'current income' and 'Permanent Income Hypothesis' (PIH) households as – for example - in Campbell and Mankiw (1991) and Auerbach and Gorodnichenko (2012) or to the distinction between 'savers' and 'borrowers' as in Eggertson and Krugman (2012). These distinctions introduce heterogeneity in consumption propensities with respect to income and net assets and explain differences in fiscal multipliers. In disaggregated models with input-output cores (CGE or macroeconomic), household heterogeneity implies that different income-to-consumption reactions plus socio-demographic characteristics like age can have an impact on economic structure and on aggregate economic outcomes (Kim et al., 2015).

In this paper, a methodology for implementing the direct impact of the COVID lockdown into a nested model of private consumption with household heterogeneity, typically used in disaggregated models like CGE (Landis and Heindl, 2016) or macroeconomic input-output (Kim et al., 2015), is laid down. This direct impact represents a supply constraint for certain goods and consumption categories that interacts with other factors (prices, income, socio-demographic characteristics) in determining the level and structure of consumption expenditure. The crucial part of the methodology is implementing this interaction in a consistent way, so that supply constraints can be treated as exogenous factors and changed accordingly. The direct and exogenous changes in the level and structure of consumption will then further lead to general equilibrium feedbacks (indirect effects) in the full model. These feedbacks are not the focus of this paper. Instead, only the direct effects of supply constraints like the COVID lockdown are presented. The two main objectives of the paper are (i) establishing a consistent methodology for introducing the exogenous inputs for simulating a COVID lockdown scenario in any macroeconomic model and (ii) calculating the short-run direct effects of the lockdown. Identifying and specifying the exogenous inputs on the one hand and the short-run impacts on the other hand, is based on the definition and the timing of the consumption rebound after the lockdown.

The rebound of consumption determines, if and to what extent the short-term increase in saving will be compensated in the same or in the following year in order to rebalance the transitory and enforced increase in the savings rate. As far as possible, the rebound effect that disperses across the same or the following year, is derived from the theoretical base of the model properties. From a theoretical point of view, 'PIH' households or 'savers' according to Eggertson and Krugman (2012), should exhibit a complete rebound in their consumption behavior, as they adjust for the short-run surprise in consumption. This adjustment may take place in the following period, especially for durable consumption, that exhibits adjustment costs (Caballero (1994) and Sarantis and Stewart (2003)). For current income consumers or 'borrowers' (Eggertson and Krugman, 2012) the rebound is complete as well, as far as their optimizing behavior and optimal stock of durables is concerned. As these consumers react to shocks in the optimal durable stock in a backward-looking manner, part of the rebound does not take place in the same or the following year, but spreads out to a longer period. These consumers therefore face short-run durable consumption losses (as defined here) and less durable expenditure means less saving for down payments and thereby loosens the liquidity constraints of these household groups.

Additionally, other factors of the lockdown induced recession like income uncertainty (Bayer et al., 2020) and income decreases from investment and export demand shocks will play a role for consumption. It must be noted that this type of effects can only be inferred from solutions of a full model, that incorporates all macroeconomic feedbacks. Total consumption can still decrease significantly in a model simulation, although a full rebound of the savings rate is assumed in the calculation of the *exogenous* model inputs. This can be the consequence of income and wealth effects, other demand effects (investment, exports), price effects that also effect the real interest rate, and other factors like income uncertainty (measured – for example - by the unemployment probability). All these secondary effects work in the full model (CGE or macroeconomic) and are not included in the exogenous inputs for simulating a COVID lockdown scenario.

The methodology lined out can be applied to disaggregated models of consumption, where at the aggregate level total consumption is determined and then is split up into categories or goods according to a demand system that is based on a direct or indirect utility or an expenditure function. The aggregate consumption function is specified for total durable and total non-durable consumption and the latter is then to be split up into single goods. In practice, the splitting up into goods often comprises two nests, where the first splits up into main categories applying a fully-fledged demand system and the second nest splits the main categories up, applying simple allocation mechanisms. The degree of disaggregation of the first nest is usually limited due to limited operability of advanced demand systems with too many categories and due to the lack of viability of econometric estimation of parameters for too many categories. Therefore, in order to split up consumption to the individual good and service level, a second nest is needed. This second nest can be simply described by fixed volume shares of goods or by Cobb Douglas preferences, implying fixed expenditure shares of goods. An additional dimension introduced is the number of different household income groups. The approach applied in this study differentiates between consumers that are liquidity constrained and dynamic optimizing households according to the PIH. These groups exhibit different expenditure functions for durable and non-durable consumption and for the relationship between the two. In general, the household groups have different consumption patterns as well as different behavioral reactions of consumption with respect to prices or income. The model is applied to a calibrated consumption model with ten income groups (deciles) for Austria.

The supply constraint can be effective at the level of categories of (i) durables, (ii) the first nest or (iii) the second nest, depending simultaneously on the nature of the shock and on the aggregation structure of the model. A lockdown shock to some durable categories (for example vehicles) will be fully adjusted in total durable spending during the current and the following period in the case of ‘PIH’ consumers. In the case of current income consumers, less durable spending for some categories loosens the liquidity constraint due to lower down payments, leading to an adjustment in non-durable expenditure. Similar substitution effects work at the first nest of consumption allocation: supply constraints at the first nest change the budget shares at this nest. Another result of the methodology presented here is that supply constraints at the second nest also exert a feedback on the consumption structure at the first nest. Accounting for all these factors of influence, important substitution effects in terms of budget share changes can be observed at the first nest with simultaneously rising (food/beverages, appliances, health) and falling (clothing, other services) shares.

The short-run direct effects of the lockdown in period *t* amount to an aggregate consumption effect of – 0.7% for liquidity constrained households and of -0.4% for those households that are not liquidity constrained. The aggregate effect for non-durables is different for both household types (+1.1% for liquidity constrained households and -0.4% for PIH households). PIH households simply sluggishly adjust their durable stock and their consumption rebound, whereas liquidity constrained households envisage less saving for down payments with less durable expenditure. The changes in budget shares at the first nest amount to a maximum of 2 percentage points with some heterogeneity across household groups. The changes in the sub-shares of the second nest are considerably larger, as most of the supply constraints concern the level of individual goods and services. The exogenous inputs for a CGE or macroeconomic model are made up by the shocks to aggregate consumption in period t and $t + 1$, as well as by the shocks to the budget shares.

These results for the exogenous model inputs reveal that the supply constraints from a lockdown trigger significant structural changes in demand. If all quantities and prices in the economy adjust instantaneously and smoothly to these structural shocks, adjustment costs are expected to be small and *vice versa*. This might be especially relevant for the labor market.

1. Aggregate private consumption of heterogenous households

The methodology presented here is – as much as possible - encompassing for different specifications and theoretical concepts of private consumption. The main issue is dealing with different dimensions of heterogeneity, as consumption is split up into categories and goods on the one hand and into consumption of different household income groups on the other hand. For the first dimension, the methodology combines an aggregate consumption function for non-durables with utility maximization from a bundle of goods. Attanasio and Weber (1995) have shown that this can be seen as a two step-process, where the consumer in the first step decides the total amount of consumption in each period and in the second step the allocation of this total expenditure across goods. The links between these two steps are total non-durable consumption expenditure in a period, which determines consumption by good via an expenditure elasticity, and the aggregate consumer price index from the demand system, which determines the real interest rate (Attanasio and Weber, 1995), feeding back to total consumption demand. The level of total consumption expenditure is linked to the dynamic utility function and the allocation across goods is linked to an expenditure function with an indirect utility function.

For the second dimension, the methodology differentiates unconstrained and constrained (current income) consumers and specifies consumption functions for durables and non-durables for both types of consumers. Durable consumption and the interaction with non-durable expenditure are an important feature in consumption modeling (see, among others: Chah, et al., (1995), Alessie, et al., (1997) and Luengo-Prado (2006)). Sarantis and Stewart (2003) present a model, where durables and non-durables are aggregated in a Cobb-Douglas function of total consumption and one part of households are current income consumers. The share of current income consumers in total households is not exogenous, but endogenously determined from econometric estimations of aggregate consumption. One general result of the literature (see also: Chah et al., 1995) is that the identification of current income consumers that violates the rational PIH, does not directly legitimate the specification of simple 'rule of thumb' consumption functions of disposable income. One important line of research for explaining why long-run optimizing consumers deviate from PIH behavior is the 'buffer stock' model of saving (Carroll (1997)). Introducing savings motives like income uncertainty and down payments for durables, it has been shown empirically that the existence of income-dependence of consumption in the data is due to liquidity constraints, whereas explicit 'rule of thumb' consumption is also rejected by the data (Chah et al. (1995) and Sarantis and Stewart (2003)).

For unconstrained consumers, durable and non-durable consumption is derived from the Euler equation that is the solution to the dynamic lifetime optimization problem. For constrained consumers, durable consumption is described by a general stock adjustment model (Caballero, 1994) that takes liquidity constraints into account (Eberly, 1994). Non-durable consumption is based on the hypothesis that liquidity constrained households consume all their income. This hypothesis is adapted to the observed savings rates of these households in the data and takes into account that part of that saving is due to voluntary equity allocation and part to the down payment for durables (Luengo-Prado, 2006). The down payment is a dynamic condition in

Luengo-Prado (2006), defined as an exogenously given parameter that defines the proportion of the durable stock that cannot be financed by borrowing. In the simple case when this relationship is constant, the down payment for current purchases of durables is identical to the long-run parameter. The supply constraint for durables diminishes the collateral and therefore leads to an increase in non-durable consumption. This is based on the assumption that no substitution between different durable categories takes place.

1.1. Durable and non-durable consumption of PIH households

At the top level, total consumption of a household group (C_T) can be split up into non-durable consumption C and expenditure for durable goods, C_D with K_D as the durable stock.

$$C_T = C^{\eta}\, C_D{}^{(1-\eta)} \tag{1}$$

As Sarantis and Stewart (2003) have noted, this specification is based on the assumption of a relatively stable proportion of durable to non-durable expenditure, defined here as $w_D = \frac{C_D}{C}$, in the mid-term. The homogenous lifetime utility function from 0 to T for non-durables is given with:

$$U = \sum_{n=o}^{T} \frac{1}{(1+d)^n} \frac{\left(E_t C_{t+n}^{1-\beta} - 1\right)}{(1-\beta)} \qquad (1+d) \geq 1, \qquad \beta > 0. \tag{2}$$

In (2) (1+d) is the discount factor with discount rate i, β is the coefficient of relative risk aversion and E_tC_{t+n} is the expectation in t (given the information in t) about consumption in period $t + n$. The corresponding lifetime budget constraint that covers real non-property income earned in period M to N and property income from assets, A, can be written as:

$$(1+r)A_{t-1} + \sum_{n=M}^{N} \frac{E_t Y_{t+n}}{(1+r)^n} = \sum_{n=0}^{T} \frac{E_t C_{t+n}}{(1+r)^n} \tag{3}$$

In any period, real disposable income, YD_t, can be defined as the sum of property income on assets with real rate of return r: $YD_t = (1+r)A_{t-1} + Y_t$. This real interest rate for consumers is given by i/PC, where i is the nominal market rate and PC is a consumption price aggregator. The solution of the dynamic maximization problem of equation (2) and (3) yields the Euler equation:

$$C_t^{-\beta} = \frac{1+r}{1+d} E_t C_{t+1}^{-\beta} \tag{4}$$

Following Sarantis and Stewart (2003), this equation can be approximated by an explicit dynamic consumption function, as the expected logC_t and logC_{t+1} only differ by a ‘surprise’ ε_{t+1}:

$$\Delta log C_{t+1} = \mu + \sigma r_{t+1} + \varepsilon_{t+1} \tag{5}$$

The parameter $\sigma = 1/\beta$ is the intertemporal elasticity of substitution and the constant μ is given with $\mu = (1/\beta)\log[1/(1 + d)]$. Equation (5) is an approximation to the expression derived from the Euler equation: $\Delta log C_{t+1} = \mu + \left(\frac{1}{\beta}\right) \log\left(1 + E_t r_{t+1}\right) + \varepsilon_{t+1}$.

For durable consumption an approach along the lines of Caballero (1993, 1994) is assumed. It is also based on the decision of a PIH consumer, but incorporates sluggish adjustment to surprises to durable demand, $\varepsilon_{D,t}$:

$$\Delta log K_t = \mu_D + \sigma r_{t+1} + \alpha \varepsilon_{D,t} + (1-\alpha)\varepsilon_{D,t-1} \tag{6}$$

When K_t depreciates with a given rate of depreciation δ, then for the durable expenditure CD_t we have: $\Delta K_t = \Delta log K_t (K_{t-1}) = CD_t - \delta K_{t-1}$.

As Caballero (1994) has shown empirically, durable consumption according to equation (6) can be described by a moving-average (MA) error process. Equation (5) and (6) describe the long-run development of both consumption categories which can be substituted into (1) in order to determine total consumption.

1.2. Durable and non-durable consumption of liquidity constrained households

The literature on the PIH (e.g. Chah et al. (1995) and Sarantis and Stewart (2003)) suggests that violation of the PIH does not necessarily mean that consumers follow a 'rule of thumb' process with disposable income as explanatory variable. According to the empirical results, these households should rather be modelled as dynamic maximizers that face liquidity constraints and therefore behave like 'current income' consumers. Sluggish adjustment of the durable stock also plays a role for constrained consumers and can, according to Caballero (1993) and Eberly (1994), be described as an error correction model (ECM) of adjustment of an actual durable stock (K_t) towards an optimal long-run stock (K^*_t). The optimal stock depends on the real interest rate and can be described by equation (6) as in the case of unconstrained consumers and $\tau_K < 0$ is the error correction coefficient. The most generic function for durable consumption of liquidity constrained households therefore simply consists of extending equation (6) by a term for disposable income:

$$\Delta logK_t = \alpha_D + \sigma r_t + c_{Y,D}\Delta logYD_t + \tau_K[logK_{t-1} - logK^*_{t-1}] \quad (7)$$

$$\Delta logK^*_{t-1} = \mu_D + \sigma r_t + \alpha\varepsilon_{D,t-1} + (1-\alpha)\varepsilon_{D,t-2} \quad (8)$$

Behavior of liquidity constrained households leads to a violation of the PIH, because lagged income becomes a predictor of expenditure and is backward instead of forward looking according to the ECM mechanism. Note that the income term in (7) can be seen as an approximation of measuring the influence of liquidity constraints. Therefore, one could alternatively search for variables explicitly measuring the influence of liquidity constraints, as Sarantis and Stewart (2003) have shown in their estimations.

The same holds for nondurable consumption. Assuming that liquidity constrained households can also be described as current income consumers for this consumption category, the impact of liquidity constraints needs to be considered for this expenditure category as well. Following Luengo-Prado (2006), the liquidity constraint consists of a limit to household debt and of the collateral. Part of the durable stock θ must be hold in equity and thereby reduces the funds (in Luengo-Prado (2006) given by all resources of the household, defined as 'cash-in-hand') for consumption. That means that a current income consumer that fully uses up disposable income can only consume part of this income, as another part needs to be saved for down payment for durables. The down payment is defined as a stock relationship with respect to K_t. If this relationship defined by θ shall be kept constant, it also applies to current durable consumption, ΔK_t:

$$C_t = c_Y[YD_t - \vartheta\Delta K_t] \quad (9)$$

If $c_Y < 1$, the household additionally saves voluntarily, building up an asset stock. Taking into account depreciation of the durable stock gives $\Delta K_t = C_{D,t} - \delta K_{t-1}$ and non-durable consumption becomes:

$$C_t = c_Y\left[YD_t - \vartheta C_{D,t} + d_K K_{t-1}\right] \quad (10)$$

with $d_K = \theta\,\delta$. From (10), an elasticity of non-durable consumption w.r.t. durable consumption can be derived: $\frac{\partial logC_t}{\partial logC_{D,t}} = -w_D(c_Y\vartheta) < 0$, where $w_D = \frac{C_D}{C}$, as defined above. This relationship weights the product of the average propensity of consumption for non-durables and of the down payment.

1.3. Supply constraints for aggregate durable and non-durable consumption

The total consumption impact of the supply constraints due to the lockdown is given by aggregating durable and non-durable expenditure including the impact of the supply constraint according to equation (1). The impact of the supply constraints implicitly already contains the rebound effects at all nests of the consumption model that occur in *t* and *t* + 1:

$$log\bar{C}_{T,t} = \eta log(\bar{C}_t) + (1-\eta)\log\bar{C}_{D,t} \qquad t = 0,1 \qquad (11)$$

where $\bar{C} = \sum_{h=1}^{H}\bar{C}^h$ and $\bar{C}_D = \sum_{h=1}^{H}\bar{C}_D^h$ is the aggregation across household groups *h*.

The rebound effect occurs in *t* = 0 and *t* = 1 and in some cases the allocation to the two periods directly follows from theory and in some cases needs to be carried out by the modeler, according to additional and actual data. By default, the total rebound effect $\rho = \rho_t + \rho_{t+1} = 1$, so that a full compensation of the shock to the savings rate occurs over the two periods. That applies to the rebound effects at the lower nests (s. the sections below) and to the behavior of forward-looking PIH households. Both total non-durable and total durable expenditure are therefore only affected by supply constraints plus rebound at the aggregate level. There are potential feedbacks from rebounds at the first and second nest of consumption, which are not effective over both periods *t* and *t* + 1 due to a full rebound at these levels. They can however play a certain role in each period, depending on the allocation of ρ across *t* and *t* + 1, but this is not analyzed here.

The backward-looking liquidity constrained households cannot fully react in their durable expenditure to the lockdown shock and therefore only in *t* + 1 they adjust part of the shock to durables. Given that non-durable expenditure of these households is liquidity-constrained by the down payment for durables, the fact that the rebound effect for durables is only partial in *t* and *t* + 1 leads to higher non-durable expenditure.

For PIH households the rebound effect in *t*, ρ_t, directly compensates for the supply constraint, covered by the 'surprise', ε_t:

$$\Delta log\bar{C}_t = \mu + \sigma r_t + \varepsilon_t - \rho_t\varepsilon_t \qquad (12)$$

Durable consumption of PIH households is subject to sluggish adjustment and therefore, the rebound is also spread out to both periods:

$$\Delta log\bar{K}_t = \mu_D + \sigma r_{t+1} + \alpha\varepsilon_{D,t} + (1-\alpha)\varepsilon_{D,t-1} - \rho_t\varepsilon_{D,t}$$
$$\Delta log\bar{K}_{t+1} = \mu_D + \sigma r_{t+2} + \alpha\varepsilon_{D,t+1} + (1-\alpha)\varepsilon_{D,t} - \rho_{t+1}\varepsilon_{D,t} \qquad (13)$$

The lockdown impact in *t* works in a first step on $\overline{CD}_t = \Delta log\bar{K}_t(K_{t-1}) + \delta K_{t-1}$ and is contained in the corresponding 'surprise' $\varepsilon_{D,t}$, which is compensated by the rebound in *t*. As due to $0 < \alpha \leq 1$, only part of the lockdown shock itself impacts in *t*, so that another part is carried over to *t* + 1, namely (1- α)$\varepsilon_{D,t}$. In the next period, the rebound ρ_{t+1} is active, yielding: $\alpha\varepsilon_{D,t} + (1-\alpha)\varepsilon_{D,t} = -[\rho_t\varepsilon_{D,t} + \rho_{t+1}\varepsilon_{D,t}]$. The initial supply constraint is fully compensated by the total rebound in the two periods and $\overline{CD}_{t+1}$ adjusts accordingly. The exact exogenous inputs in *t* and *t* + 1 for a model simulation can be derived by the allocation of the total rebound between the two periods. This additional assumption can be done based on additional information, e. g. from business and consumer surveys. In the case that $\alpha = -\rho_t$ and $1-\alpha = -\rho_{t+1}$, the rebound would exactly compensate the impact of the lockdown in both periods.

For liquidity constrained households, the supply constraint implemented in $\varepsilon_{D,t}$ and the compensation by the rebound for the optimal long-run stock (K^*_t) are the same as described in (13) and yield the two period values for the supply constraint optimal stock, $\bar{K}_t^*$ and $\bar{K}_{t+1}^*$. Liquidity constrained households are agents that would behave according to the same dynamic maximization principle as PIH households, if no liquidity constraints existed. That gives the following impact on the optimal durable stock in *t*:

$$\Delta log\bar{K}_t^* = \mu_D + \sigma r_{t+1} + \alpha\varepsilon_{D,t} + (1-\alpha)\varepsilon_{D,t-1} - \rho_t\varepsilon_{D,t} \qquad (14)$$

The supply constraint $\varepsilon_{D,t}$ is the same as in the unconstrained case and both α and ρ_t have the same value as well and determine the impact on the optimal stock in period *t*.

At the same time, the lockdown impact in *t* restricts the actual durable consumption and the durable stock in *t* is fully affected:

$$\Delta log\overline{K}_t = \alpha_D + \sigma r_t + c_{Y,D}\Delta logYD_t + \tau_K[logK_{t-1} - logK^*_{t-1}] + \varepsilon_{D,t} \quad (15)$$

The major difference in the behavior of liquidity constrained households, compared to the unconstrained, is that adjustment takes place backward looking and shocks as well as rebounds in the actual stock are not lagged due to this behavior and not only due to adjustment costs. Therefore, the supply constraint fully hits the actual durable stock in *t*, whereas it is spread out to the two periods and compensated by the rebound in the two periods only in the case of the optimal stock.

For the actual durable stock in period *t*+1, one gets in the constrained case:

$$\Delta log\overline{K}_{t+1} = \alpha_D + \sigma r_{t+1} + c_{Y,D}\Delta logYD_{t+1} + \tau_K[log\overline{K}_t - log\overline{K}^*_t] \quad (16)$$

where $\overline{K}^*_t$ is determined according to (14) and $\overline{K}_t$ according to (15).

The actual stock is fully hit in period *t*, whereas the optimal stock is only hit with $\alpha\varepsilon_{D,t}$ and at the same time compensated with rebound $\rho_t\varepsilon_{D,t}$. The net impact on the optimal stock therefore depends on the distribution of shocks vs. rebounds, given by the parameters α and ρ_t. In the case of $\alpha = -\rho_t$, the optimal stock in *t* is not affected by the supply constraint plus rebound. As the actual stock is always affected by the supply constraint ($\overline{K}_t < K_t$), in this case of $\overline{K}^*_t = K^*_t$ a positive effect on $\overline{K}_{t+1}$ will be triggered by $\tau_K[log\overline{K}_t - log\overline{K}^*_t]$.

For calculating the effects of supply constraints plus rebounds on non-durable expenditure of liquidity constrained households, the induced changes in the actual stock in *t* and *t*+1 need to be first converted into constrained durable expenditure in both periods via $\overline{CD}_t = \Delta log\overline{K}_t K_{t-1} + \delta K_{t-1}$ and $\overline{CD}_{t+1} = \Delta log\overline{K}_{t+1}\overline{K}_t + \delta\overline{K}_t$. Then given the loosening of the liquidity constraint due to less down payment, the impact on non-durable expenditure is quantified by:

$$\bar{C}_t = c_Y\left[YD_t - \vartheta\bar{C}_{D,t} + d_K K_{t-1}\right]$$
$$\bar{C}_{t+1} = c_Y\left[YD_{t+1} - \vartheta\bar{C}_{D,t+1} + d_K\overline{K}_t\right] \quad (17)$$

Equations (12) to (17) quantify the lockdown plus rebound impact of the temporary supply constraint, which is only active during the lockdown, at the aggregate level for the two household types. It must be noted again, that these impacts represent the direct effects of the supply constraints plus rebounds. At the same time, they represent exogenous shocks, which can be directly inserted into any macroeconomic or CGE model by simply changing exogenous shock variables (error terms). All further indirect effects on consumption are then results of the full model simulation that incorporates all macroeconomic (general equilibrium) feedbacks, like price effects, disposable income effects, income uncertainty (unemployment probability), and others.

Along the nested structure of the consumption model, consumption rebounds taking place at the same nest as the corresponding supply constraint can be identified. As these rebounds are equal to unity over both periods (*t* and *t* + 1), no consumption losses are passed through to total consumption of the same nest. The nested structure of the model links the different nests, and therefore potential consumption rebounds affecting the upper nest of where the supply constraint is effective could happen. This potential upstream consumption rebound works through aggregation of rebounds at the lower level, affecting the bundle at the next level nest. The theoretical base of the tow step-decision process of consumers implies that this kind of rebound is equal to unity and does not lead to overall consumption losses.

2.The first nest: A demand system

The bundle C_t is further split up into several demand categories *k*, which in turn are aggregates of the lowest level of goods, *i*. According to Attanasio and Weber (1995) this can be seen as a two-step decision process of consumers, where in the first step she decides total expenditure in a period *t* and in a second step the splitting up of this total expenditure across the categories *k*. Starting point are the non-durable expenditure functions of unconstrained and constrained consumers, i.e. the log-linearized simple Euler equation with supply constraints (12) and the 'current income'-equation (10) with supply constraints that may be written with the explicit consumer price aggregator *PC* as part of the real interest rate, *r*:

$$\Delta log\bar{C}_t = \mu + \sigma\frac{i_t}{PC_t} + \varepsilon_t - \rho_t\varepsilon_t \tag{12a}$$

$$\bar{C}_t = c_Y\left[\frac{YD_{n,t}}{PC_t} - \vartheta\bar{C}_{D,t} + d_K K^*_{t-1}\right] \tag{10a}$$

In (10a) $YD_{n,t}$ is the nominal disposable income. Applying a Divisia price index to consumption gives nominal expenditure $\bar{C}_{n,t}$ for all household groups as $log\bar{C}_{n,t} = log\bar{C}_t + logPC_t$.

A widely used demand system for allocation of total expenditure across goods or categories is the Almost Ideal Demand System (AIDS, s.: Deaton and Muellbauer (1980)), which is based on an expenditure (C_n) function with two price vectors *a*(*p*) and *b*(*p*):

$$logC_n(u,p) = (1-u)log[a(p)] + ulog[b(p)] \tag{18}$$

where *u* is the corresponding utility level (0 = subsistence and 1 = bliss) and the price functions are:

$$loga(p) = \alpha_0 + \sum_i \alpha_i logp_i + \frac{1}{2}\sum_i\sum_j \gamma'_{i,j}\, logp_i logp_j$$

$$logb(p) = loga(p) + \beta_0\prod_j p_j^{\beta_j} \qquad i,j = k \tag{19}$$

The AIDS expenditure function is homogenous in *p* and given with:

$$logC_n(u,p) = \alpha_0 + \sum_i \alpha_i logp_i + \frac{1}{2}\sum_i\sum_j \gamma'_{i,j}\, logp_i logp_j + u\beta_0\prod_j p_j^{\beta_j} \tag{20}$$

In (19) and (20) $\gamma'_{ij} = \frac{1}{2}(\gamma_{ij} + \gamma_{ji})$. By Shephard's Lemma, in a first step an expression for the budget shares of the *k* categories $\frac{\partial logC(u,p)}{\partial logp_k} = \frac{p_k x_k}{C(u,p)}$ can be derived as a function of *p* and *u*. This expression can be inverted to yield the indirect utility function and in a second step, by inserting it again into the first expression, gives the budget shares of a household group *h*:

$$\overline{w}_k^h = \alpha_k^h + \sum_j \gamma_{kj} logp_j^h + \beta_k(logC_n^h - logPC^h) + \xi_k \tag{21}$$

The nominal budget shares of each household group with supply constraints $\overline{w}_k^h$ are functions of prices, total expenditure and a supply constraint, ξ_k for category *k*. The total non-durable expenditure in (21) is the variable without supply constraint at that aggregate level, i. e. C_n^h and not $\bar{C}_n^h$. For unconstrained consumers this is irrelevant, as $\bar{C}_n^h = C_n^h$. For constrained consumers, the impact of the supply constraints plus rebounds on the level of consumption of category *k* is a twofold process: at the aggregate level total non-durable consumption might change due to changes in durable consumption and at the level of *k* the supply constraint may directly affect a certain category. In (21) the parameters for price and expenditure reactions of consumption demand γ_{kj} and β_k are not household-group specific, only the constant α_k^h. The price index PC^h is household group-specific and defined by log *a*(*p*):

$$logPC^h = \alpha_0 + \sum_k \alpha_k^h logp_k^h + \frac{1}{2}\sum_k\sum_j \gamma_{k,j}\, logp_k^h logp_j^h \tag{22}$$

Note that the price aggregator PC^h is household group-specific due to household specific parameters α_i^h at the first nest level plus differences in the consumption structures at the second nest level of the single goods. The latter lead to different single category prices p_k^h, because the categories k are different aggregates of the single goods for each household group.

Additivity of budget shares, homogeneity and symmetry in the expenditure function imply the following parameter restrictions:

$$\sum_k \alpha_k^h = 1 \qquad \sum_k \gamma_{k,j} = 0 \qquad \sum_j \gamma_{k,j} = 0 \qquad \gamma_{k,j} = \gamma_{j,k} \tag{23}$$

Additionally, the supply constraints ξ_k must sum up to zero, i. e. $\sum_k \xi_k = 0$. The supply constraint is usually given as a percentage change in consumption of k, $r_k < 0$, so that $\bar{c}_k^h = (1 + r_k)c_k^h$. This can be directly converted into a change in the budget share:

$$\bar{\xi}_k = \frac{r_k c_k^h}{C_n^h} \frac{p_k}{PC^h} \tag{24}$$

In (24) $\bar{\xi}_k$ is the exogenously fixed supply constraint at the level of nest 1 (categories k). The first term describes the impact of the supply constraint on the volume share of consumption and the second term converts that into the budget share impact by multiplying it with the relative price (with PC^h as the household group-specific price of the bundle C). Equation (24) does not take into account that total non-durable expenditure might have changed, but only describes the corresponding impact of the supply constraint on the share. The change in total non-durable consumption that – including the rebound – can only appear in the case of liquidity constrained households, is left to a separate part of the effect on the consumption level of k.

Introducing the supply constraint $\bar{\xi}_k$ at this nest, implies that no supply constraint at the lower level of the i goods of which this category k is composed, is introduced simultaneously. In the case of a category k that consists only of a few goods which are just different specifications of k (e. g. wearing apparal and leather/shoes as goods of the category 'clothing'), it is more likely that the supply constraint will be introduced at the level of k than of i. In the case of broad categories at the level of k (e. g. 'services'), the introduction of supply constraints at goods level i becomes more likely. Therefore, supply constraints may be effective at both nests, but the introduction at nest one or nest two is exclusive and depends on how the actual supply constraints match with the aggregation structure of the model.

The price and expenditure elasticities are not relevant for the exercise presented here, as the supply constraints directly do not lead to price and expenditure changes. This is only the case in the full-fledged model. Once the supply constraint has been implemented into (21) for those categories k where it applies to, the adjustment in demand for the other budget shares j for each household group h needs to be introduced by calculating the corresponding positive demand shocks, $\bar{\xi}_j$:

$$\bar{\xi}_j = \left(\frac{w_j^h}{1 - \sum_i w_k^h}\right)\left(-\bar{\xi}_k\right) \tag{25}$$

Equations (24) and (25) describe the substitution effects within the bundle of the k categories of the first nest, triggered by supply constraints. Due to additivity of the shocks, $\bar{\xi}_k$ and $\bar{\xi}_j$, all consumption losses in categories k are fully compensated by consumption increases in categories j, if total consumption of the bundle of non-durables does not change. Consumption losses due to less than full rebounds at the level of nest 1 are ruled out by the theoretical foundation of the two step-decision process described in Attanasio and Weber (1995). The annual consumption expenditure of different household groups is determined by the lifetime utility maximization with or without liquidity constraints. At the second step, i. e. at nest 1, this total consumption expenditure is taken as given and allocated across consumption categories. There are however, as Attanasio and Weber (1995) have shown as well, feedbacks from general equilibrium effects in the price system on PC according to (22) and therefore on total non-durable consumption, via a real income and a real interest rate-effect. Changes in total consumption resulting from supply constraints plus rebounds according to (10a) and (12a) for liquidity constrained consumers need to be taken into account for calculating the direct effects at the level of k for the total of period t and t+1: $\bar{c}_k^h = \bar{w}_k^h \bar{C}_n^h$.

3. The second nest: Fixed shares of consumption goods

The second level of aggregation corresponds to the level of single goods, i. The splitting up is simply given by fixed volume shares, $s_{i,k}^h$. Alternatively, one could assume Cobb-Douglas preferences at this nest, implying fixed *nominal* shares. For the case of the exercise shown here, that does not change outcomes, as prices do not change directly with the implementation of supply constraints. The level of consumption of good i, when a supply constraint is active at the second nest, is given by:

$$\bar{c}_i^h = \bar{s}_{i,k}^h c_k^h \qquad (26)$$

where c_k^h is the unconstrained demand for category k. As the introduction of supply constraints at nest two or three is exclusive, the demand at nest 1 is unconstrained in the case of a supply constraint at the goods level i. The supply constraint at the second nest can be again defined via a rate of change ($r_i < 0$):

$$\bar{c}_i^h = (1 + r_i) c_i^h \qquad (27)$$

The second nest is modeled via a demand system so that substitution effects between the shares are induced by the implementation of the supply constraints. The shares for which a supply constraint is binding, are defined as:

$$\bar{s}_{i,k}^h = \frac{\bar{c}_i^h}{c_k^h} \qquad (28)$$

In principle, the definition of $\bar{s}_{i,k}^h$ includes any potential consumption rebound at the upper level-nest that is induced from changes at this nest. The theoretical foundation of the model is an integration of expenditure minimization of goods demand with lifetime utility maximization in a two-step procedure. The dynamically optimal total demand is split up into categories and goods in two nests, where the consumption at the next aggregation level is given in each case. Therefore, as in the case of nest 1, the rebound of the supply constraints for period t and t+1 is also complete at this second nest.

Once the supply constraints for $\bar{s}_{i,k}^h$ have been implemented, the other budget shares $s_{j,k}^h$ need to be adjusted proportionally:

$$\bar{s}_{j,k}^h = \left(\frac{s_{j,k}^h}{1 - \sum_i s_{i,k}^h}\right)\left(1 - \sum_i \bar{s}_{i,k}^h\right) \qquad (29)$$

Equation (29) defines the substitution effects triggered by the supply constraints at the second nest.

4. Empirical results of the full consumption model

The model laid down above follows a partial equilibrium perspective and offers two options of application. One is the derivation and calculation of the direct impact of supply constraints plus rebounds on the level of consumption by good, by category, and on total consumption. For this perspective, the impacts in the first period (t) and in the second period (t + 1) are differentiated in what follows. The other option is converting these changes into changes in those exogenous variables that can be introduced into the model in a consistent way without directly disturbing those mechanisms that determine consumption by good, by category, and total consumption. For this second option, the results are shown here as the sum over the two periods. The modeler that operates a dynamic model, needs nevertheless split up the exogenous impacts within the two periods.

At the upper level, for calculating direct consumption impacts, for PIH households the following equations are needed:

$$\Delta log\bar{C}_t = \mu + \sigma r_t + \varepsilon_t - \rho_t \varepsilon_t \quad (12)$$

$$\Delta log\bar{K}_t = \mu_D + \sigma r_{t+1} + \alpha \varepsilon_{D,t} + (1-\alpha)\varepsilon_{D,t-1} - \rho_t \varepsilon_{D,t}$$

$$\Delta log\bar{K}_{t+1} = \mu_D + \sigma r_{t+2} + \alpha \varepsilon_{D,t+1} + (1-\alpha)\varepsilon_{D,t} - \rho_{t+1}\varepsilon_{D,t} \quad (13)$$

The supply constraints are comprised in ε_t and $\varepsilon_{D,t}$.Parameter values for α and the two ρ need to be assumed in order to carry out the calculations. In order to convert changes in the durable stock into changes in durable spending, a depreciation rate needs to be given. The values of shocks and rebounds (ε_t, $\varepsilon_{D,t}$, α, ρ_t and ρ_{t+1}) represent the exogenous impacts for the model.

For liquidity constrained households, the following equations determine the impacts:

$$\Delta log\bar{K}_t^* = \mu_D + \sigma r_{t+1} + \alpha \varepsilon_{D,t} + (1-\alpha)\varepsilon_{D,t-1} - \rho_t \varepsilon_{D,t} \quad (14)$$

$$\Delta log\bar{K}_t = \alpha_D + \sigma r_t + c_{Y,D}\Delta logYD_t + \tau_K[logK_{t-1} - logK_{t-1}^*] + \varepsilon_{D,t} \quad (15)$$

$$\Delta log\bar{K}_{t+1} = \alpha_D + \sigma r_{t+1} + c_{Y,D}\Delta logYD_{t+1} + \tau_K[log\bar{K}_t - log\bar{K}_t^*] \quad (16)$$

$$\bar{C}_t = c_Y\left[YD_t - \vartheta \bar{C}_{D,t} + d_K K_{t-1}\right]$$

$$\bar{C}_{t+1} = c_Y\left[YD_{t+1} - \vartheta \bar{C}_{D,t+1} + d_K \bar{K}_t\right] \quad (17)$$

The variables to implement exogenously supply constraints and rebounds are the same as in the PIH case: ε_t, $\varepsilon_{D,t}$, α, ρ_t and ρ_{t+1}. Additionally, parameter values for τ_K, $c_{Y,D}$ and ϑ need to be taken from the literature and the data for calculating the direct effects.

At the first nest (categories *k*), the full model comprises the equations for budget shares:

$$\bar{w}_k^h = \alpha_k^h + \sum_j \gamma_{kj} logp_j^h + \beta_k(logC_n^h - logPC^h) + \xi_k \quad (21)$$

$$\bar{\xi}_k = \frac{r_k c_k^h}{C_n^h}\frac{p_k}{PC^h} \quad (24)$$

$$\bar{\xi}_j = \left(\frac{w_j^h}{1-\sum_i w_k^h}\right)\left(-\bar{\xi}_k\right) \quad (25)$$

Changes in budget shares total consumption resulting from supply constraints plus rebounds ($\bar{\xi}_k$ and $\bar{\xi}_j$) are the exogenous model inputs. They yield, together with the aggregate impact on non-durable expenditure, the direct effects at the level of *k* for the total of period *t* and *t*+1: $\bar{c}_k^h = \bar{w}_k^h \bar{C}_n^h$.

At the second nest (goods *i*), the model is made up by the supply constraints and the equations for the sub-shares:

$$\bar{c}_i^h = (1 + r_i)c_i^h \quad (27)$$

$$\bar{s}_{i,k}^h = \frac{\bar{c}_i^h}{c_k^h} \quad (28)$$

$$\bar{s}_{j,k}^h = \left(\frac{s_{j,k}^h}{1-\sum_i s_{i,k}^h}\right)\left(1 - \sum_i \bar{s}_{i,k}^h\right) \quad (29)$$

The supply constraints r_i represents the exogenous model inputs at this nest. The direct consumption impacts must be calculated by combining the constrained sub-shares ($\bar{s}_{i,k}^h$ and $\bar{s}_{j,k}^h$) with the constrained level of consumption at the category level: $\bar{c}_j^h = \bar{s}_{j,k}^h \bar{c}_k^h$. That means that potentially many positive impacts on consumption as a consequence of supply constraints plus rebounds are possible. If at the category level a positive shift occurs towards a certain category and at the second level one of the goods falling in this category is constrained, the other goods will exhibit a positive impact.

4.1. Model calibration

The model has been applied to a model of private consumption for the Austrian economy that comprises one aggregate level and two nests (for the exact aggregation structure see the Appendix) as well as ten groups of household income (deciles), based on data for 2014. The model represents the consumption block of the large macroeconomic IO model MIO-ES (Macroeconomic Input-Output Model with Integrated Energy System) that is frequently used for energy and climate policy evaluation and energy scenarios in Austria (Kratena and Scharner, 2020). The underlying data are those aggregate results of the Austrian HBS (Household Budget Survey) published by Statistics Austria that were available at the time when MIO-ES had been constructed (wave 2009/2010). These data have been adjusted and made consistent with the National Accounts and input-output table for 2014.

At the aggregate level, total consumption is given according to equation (11). The aggregate level of non-durables for each decile (C_n^h) is defined as total non-energy non-durable expenditure, as energy demand is modelled at bottom-up models of energy and exogenous in MIO-ES (for the classification see the Appendix). Energy demand is linked to the (physical) durable stock and this category also includes energy relevant spending, like transport expenditure of households.

Durables comprise housing and vehicles and the maintenance expenditure linked to this stock. In the case of housing, the investment expenditure is not accounted in private consumption according to the concepts of national accounts, but in the real estate sector. Housing expenditure in private consumption is defined by actual and imputed rents. Only vehicles are subject to supply constraints due to the lockdown and the durable stock adjustment is carried out for this category only. That relies on estimates for the stock of vehicles for Austria by deciles (Kratena and Scharner, 2020) under the assumption of a depreciation rate of 8.75%. According to Caballero (1993), the ECM parameter (τ_K) is fixed with -0.15.

The first nest determines spending on eight non-durable non-energy categories and is specified as an Almost Ideal Demand System (AIDS). In a second nest, the eleven energy relevant consumption categories and the eight non-durable non-energy categories are further distributed across the 82 CPA categories, applying *fixed* sub-shares in volume terms (for the classification see the Appendix). All that is done at the level of the ten income groups of households (deciles).

The supply constraints (in terms of r_m, r_k and r_i) that are active due to the COVID lockdown according to recent studies and economic forecasts carried out in Austria (OeNB (2020), Baumgartner et al. (2020) and Schimann (2020)) are shown in Table 1. These are the annualized rates of change of real consumption in the corresponding consumption categories without taking into account any rebound after the lockdown has ended. The parameter α has been based on Caballero (1994) Sarantis and Stewart (2003) and is set as: α = 0.4. For the rebound according to Austrian business forecasts, the following distribution across the two periods has been assumed: ρ_t = 0.3 and ρ_{t+1} = 0.7. According to Sarantis and Stewart (2003) the share of liquidity constrained households has been assumed with 0.7, starting from the bottom of the income distribution. That means that decile 1 to 7 make up the liquidity constrained household group and decile 8 to 10 the PIH consumers. The liquidity constraint is measured by parameter ϑ that has been calculated from the data by $1-\frac{D_t}{K_t}$ where D_t is household debt. From the European HFCS (Household Finance and Consumption Survey) the relationship of household debt to income is given. Dividing this coefficient by the relationship of durable stock to income in the data used in this study, gives the debt/durable relation. On average over the first seven quintiles ϑ is equal to 0.78 with slightly higher values for decile 2 to 4.

The average consumption propensity for non-durable expenditure of liquidity constrained households out of $\left[YD_t - \vartheta\bar{C}_{D,t} + d_K K_{t-1}\right]$ calculated from the data varies by income decile and yields the following values:

decile 1: 1.002
decile 2: 0.901
decile 3: 0.853
decile 4: 0.821
decile 5: 0.798
decile 6: 0.798
decile 7: 0.776

These parameters together with the data set have been used to calculate the direct effects in *t* and the total effects over *t* and *t* + 1.

4.2. Results

The results for aggregate consumption expenditure are shown for the first year in Table 2 and Figure 1. In *t* the supply constraint on vehicles of – 25% is fully effective for liquidity constrained households (decile 1 to 7), whereas for PIH households only 0.1 ($\alpha - \rho_t$) of the shock impacts on consumption. The first year-effect on nondurable consumption of liquidity constrained households is about +1.1% (+1.5% for the bottom decile) without the two exceptions of decile 2 and 3, that show smaller impacts. In general, lower expenditure for vehicles lowers the liquidity constraint (the down payment for durables that needs to be saved) and therefore non-durable consumption increases. The average consumption propensity significantly falls in decile 2 compared to decile 1 and again in decile 3, so that the non-durable impulse is less pronounced (about +0.7%) for these two groups. For PIH consumers, both durable and non-durable expenditure change by about -0.4% due to the interplay between the effect of the lockdown shock and the rebound. Total consumption changes by -0.6% for all household groups and by -0.7% for the liquidity constraint households. Total consumption effects also comprise the changes in energy relevant expenditure (public transport, air transport) shown in Table 1.

The full impact of the lockdown plus rebound over both periods is almost zero (Table 3). That means that for PIH consumers as well as for liquidity constrained consumers the rebounds completely compensate for the lockdown induced consumption losses. It must be emphasized again, that this is a partial equilibrium picture of direct effects and of exogenous variable changes. The full impact that takes into account income, price and real interest effects, might look completely different. Evidence from economic forecasts for Austria (Schimann, 2020) shows that the real disposable income is negatively affected in 2020 (also by other demand shocks on investment and exports) and that the savings rate almost doubled. These effects could be identified in a full-fledged model (CGE or macroeconomic), given the exogenous inputs derived in this study. The full rebound for PIH households is simply explained by the fact that the lockdown is temporary and does not change the lifetime income of these households and their behavior. Liquidity constrained households are backward looking in their durable consumption and therefore fully suffer the durable shock in *t*, which slightly boosts non-durable expenditure due to less saving for the down payment. In *t* + 1, these households adjust the durable stock according to the error correction parameter in (16) and the changes in the actual ($\overline{K}_t$) and the optimal durable stock ($\overline{K}_t^*$) in *t*. As the actual stock is fully affected in *t* and the optimal stock only partly, a considerable adjustment is induced, leading to a slight overshooting reaction in *t* + 1. That explains the high overall growth rate in vehicle demand, that in turn slightly dampens non-durable consumption, again due to less saving for the down payment.

The most important results of this exercise of calculating the direct effects of supply constraints plus rebounds are the large substitution effects that can be observed. Figure 2 reveals the significant substitution effects at the first nest (k) of consumption in terms of budget shares and

Figure 3 in absolute terms (rate of change in consumption levels). These substitution effects can be observed for all household income-groups and show a not very pronounced *U*-shape, i. e. larger effects for bottom and top income groups. These substitution effect depends on the interplay between income and consumption patterns. The category 'Other services' is not included in Figure 2 and 3, as due to the full rebound within this category, it is not affected in the aggregate. Therefore, the substitution effects within this large category of consumption with an average budget share of 40% over all household income-groups are very large.

Figure 4 shows the impact at the second nest, i.e. at the level of selected CPA categories. The changes in the sub-shares induced by the supply constraints are significant and magnify the substitution effects at the first nest. This magnification effect works in both directions, i.e. for negative and positive changes. As a result, large positive and negative changes in consumption at the level of individual goods and services are induced by the supply constraints plus rebounds, even without changes in aggregate consumption. These changes clearly represent a significant challenge for the structural adjustment potential of an economy, especially for the issue of labor mobility in the short-run.

5. Conclusions

This paper presents a method of calculating the consequences of the COVID lockdown on consumption across household income groups (deciles) by treating the lockdown as a number of supply constraints. The method serves for assessing either only the direct effect of the supply constraints on consumption or for a consistent implementation of supply constraints via exogenous variables in a nested demand system. In both cases, the results derived by this methodology can be further used as input data either in macroeconomic forecasts or in model simulations.

The underlying consumption model is a heterogenous model with liquidity constrained consumers and optimizing households according to the Permanent Income Hypothesis (PIH). Both groups are different in their aggregate behavior of choosing total durable and non-durable expenditure in a certain period, but behave according to the same expenditure and indirect utility function in splitting up the total non-durable consumption across goods and services, that can be described by the Almost Ideal Demand System (AIDS). The rebound after enforced saving due to the lockdown is complete for both household types over two periods. For PIH consumers the shock to durables is spread over two periods due to sluggish adjustment of the durable stock and the rebound as well. For liquidity constrained consumers, the durable stock adjusts by backward looking-behavior and down payments for the durable stock limit the liquidity for non-durable consumption. These consumers therefore behave as if they were 'current income' consumers with a target durable stock in the long-run.

The methodology is applied with Austrian data for income deciles and yields results with a certain degree of heterogeneity across household income groups. For aggregate consumption this is due to the different deciles belonging to the two different household types (PIH consumers and liquidity constrained households). At the disaggregated level, one observes important substitution effects between consumption categories and their magnitude varies across household income-groups as well, mainly depending on consumption patterns.

The first year-effect on nondurable consumption of liquidity constrained households is about +1.1% (+1.5% for the bottom decile). For PIH consumers, both durable and non-durable expenditure change by about -0.4% in the first year. Total consumption changes by -0.6% for all household groups and by -0.7% for the liquidity constraint households. The full impact of the lockdown plus rebound over both periods is almost zero. These results represent a purely partial equilibrium perspective. After inserting the exogenous inputs in a full-fledged CGE or macroeconomic model, one might get considerable negative aggregate consumption effects due to income, price and real interest rate shocks at the macroeconomic level, as the Austrian economic forecasts also show (for example: Baumgartner et al., 2020).

The main result of this study is that even with aggregate effects of zero, one can observe considerable substitution effects between single goods and services induced by the lockdown and the rebound. These substitution effects show a slight *U*-shape pattern across income deciles. In any case, the observed large positive and negative contemporaneous changes in consumption at the level of individual goods and services might represent an important challenge for structural adjustment, especially in the labor market. They might also represent an underexposed issue in economic policy that focusses on the macroeconomic problems of the lockdown induced recession and not on structural change and potential adjustment problems.

Table 1: Supply constraints due to the COVID lockdown in Austria (rates of change)

	r
Durables	
Vehicles	-0.25
Energy/Energy relevant	
Other public transport	-0.20
Air transport services	-0.35
Categories *k*	
Clothing	-0.25
Goods and services *i*	
Textiles	-0.25
Accommodation services	-0.40
Travel agency, tour operator	-0.45
Creative, arts and entertainment	-0.35
Library, archive, museums	-0.35
Sporting services and recreation	-0.35
Other personal services	-0.35

Table 2: Direct effects (rates of change): Aggregate consumption effects in year 1 of the COVID lockdown in Austria

	Nondurables	**Total**
dec1	1.5%	-0.6%
dec 2	0.6%	-0.6%
dec3	0.7%	-0.6%
dec4	1.4%	-0.8%
dec5	1.0%	-0.7%
dec6	1.3%	-0.8%
dec7	1.3%	-0.7%
dec8	-0.4%	-0.4%
dec9	-0.4%	-0.4%
dec10	-0.5%	-0.5%

Table 3: Total effects (rates of change): Aggregate consumption effects in t and t + 1 of the COVID lockdown in Austria

	Nondurables	Vehicles	Total
dec1	-0.2%	1.2%	-0.1%
dec 2	-0.1%	1.2%	0.0%
dec3	-0.1%	1.2%	0.0%
dec4	-0.2%	1.2%	-0.1%
dec5	-0.2%	1.2%	-0.1%
dec6	-0.2%	1.2%	-0.1%
dec7	-0.2%	1.2%	-0.1%
dec8	0.0%	0.0%	0.0%
dec9	0.0%	0.0%	0.0%
dec10	0.0%	0.0%	0.0%

Figure 1: Direct effects (rates of change): Aggregate consumption effects in year 1 of the COVID lockdown in Austria

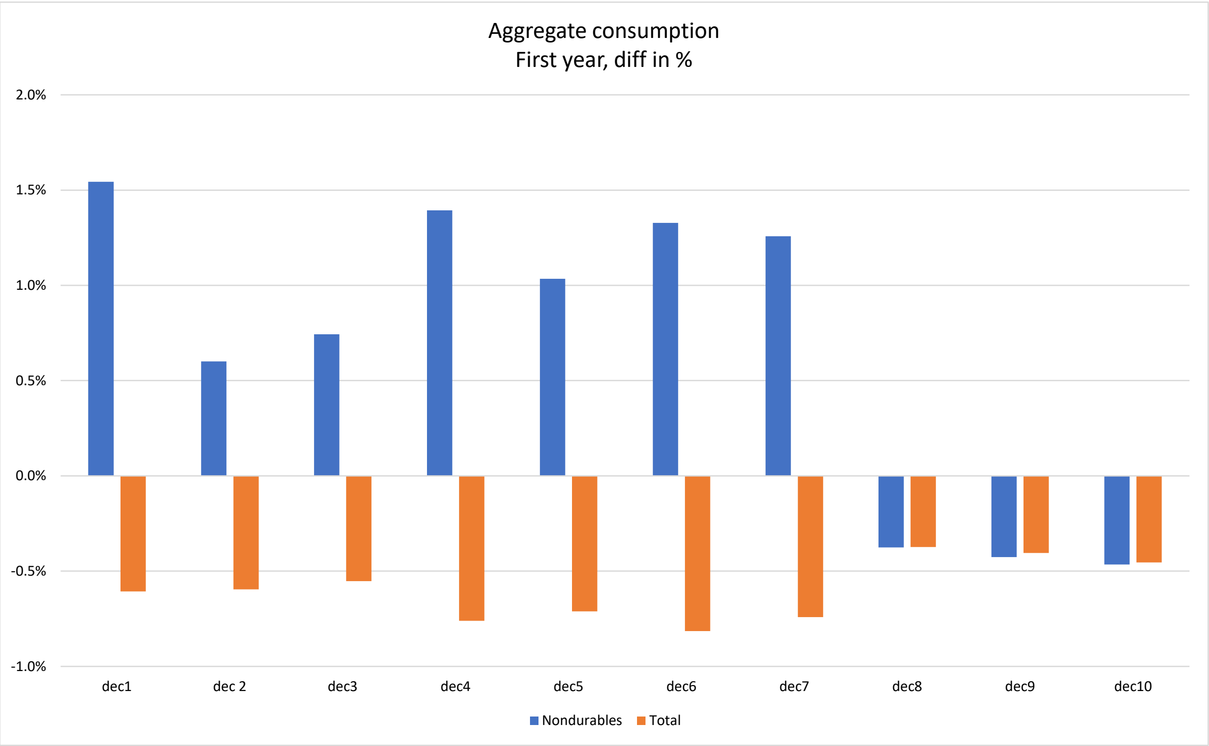


Figure 2: Substitution in consumption (change in budget shares in nest 1(k)) due to the COVID lockdown in Austria

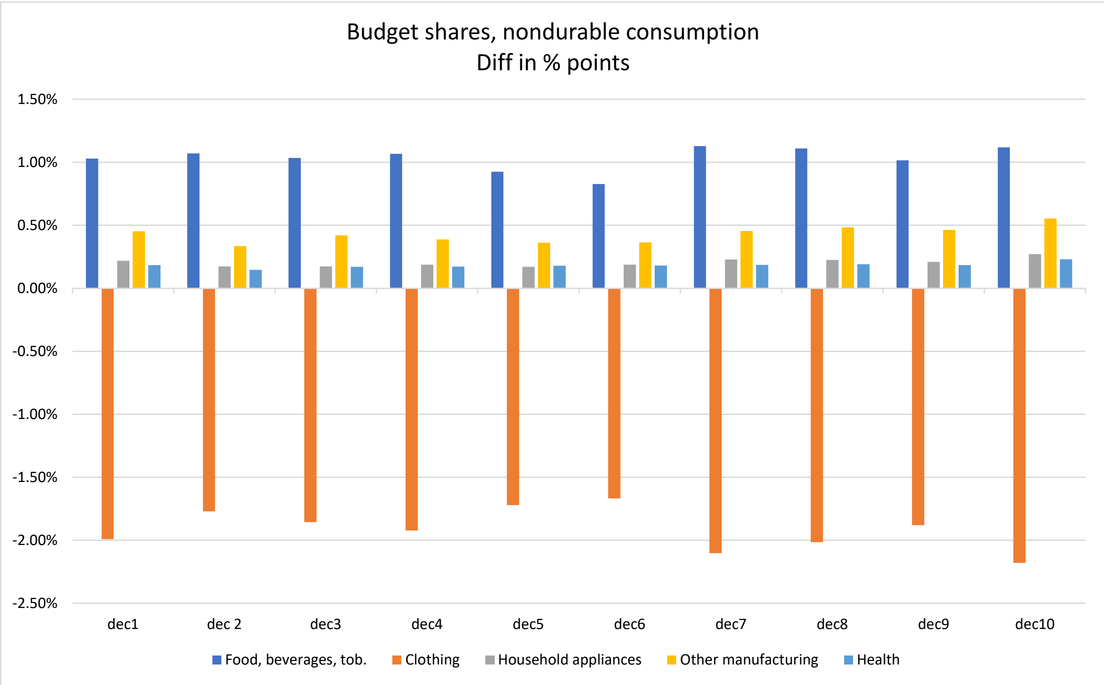


Figure 3: Consumption effects (rates of change, nest 1(k)) due to the COVID lockdown in Austria

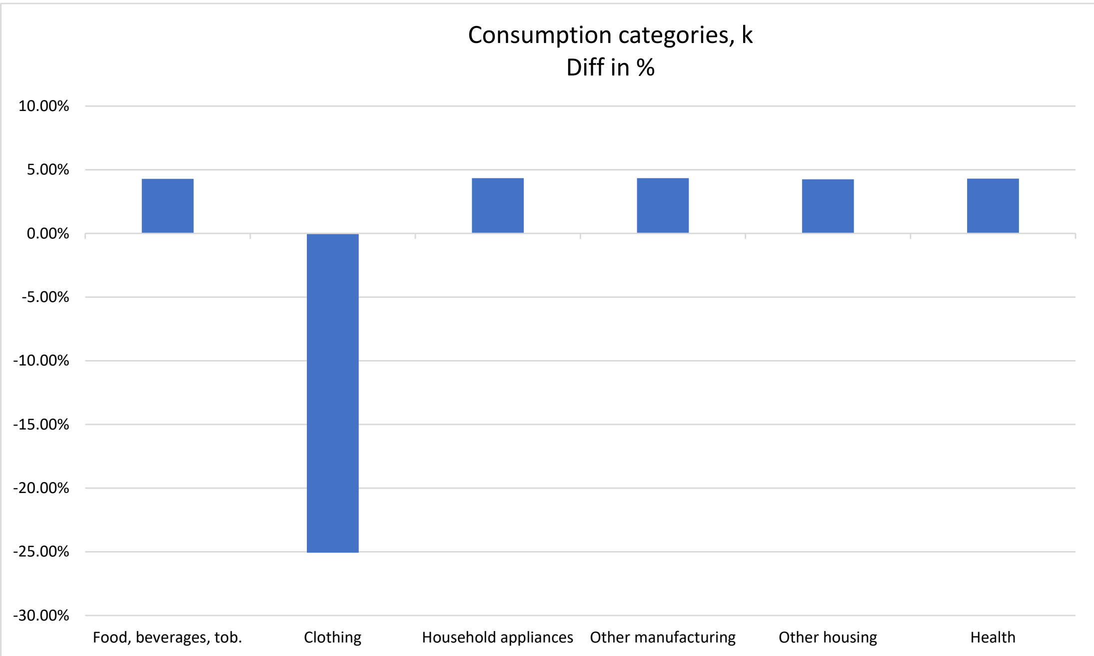
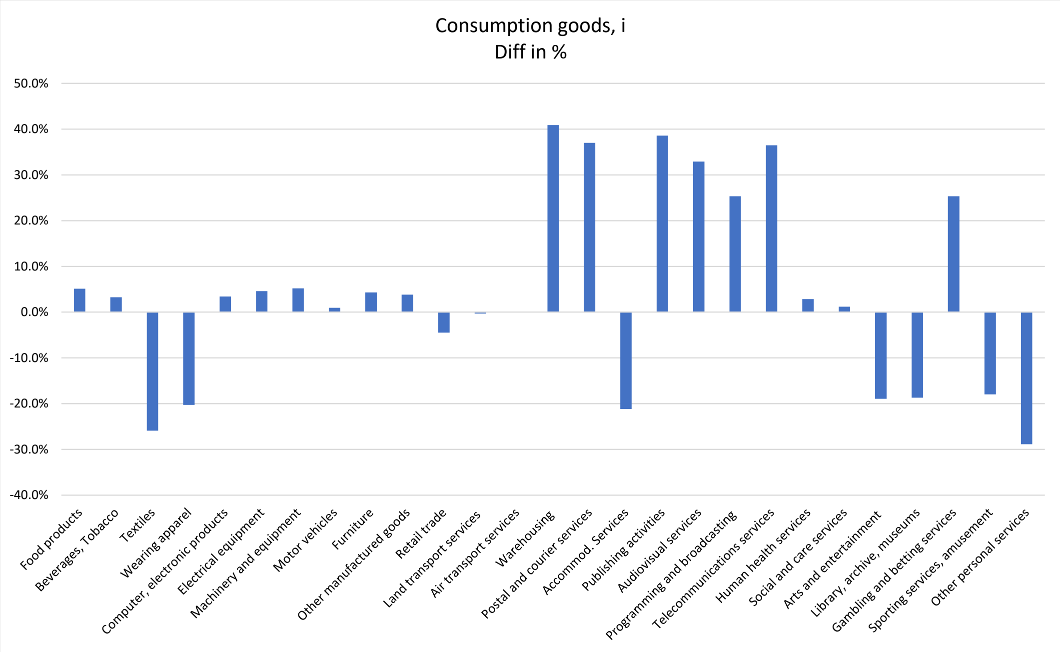


Figure 4: Consumption effects by good (rates of change) of the COVID lockdown in Austria



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Appendix: Aggregation structure and classifications

The nested model of consumption deals with energy in a separate way, inserting physical results for energy from bottom-up energy models and converting them into monetary consumption expenditure by implicit prices. The categories of energy comprise:

The general structure as described in the paper is defined by energy relevant expenditure (categories *m*) of durable and non-durable spending on the one hand and the non-energy bundle *D* of non-durables (categories *k*) on the other hand:

Table A.1: Aggregation structure (durables, energy and categories k) of the consumption model

Durables
Rents
Vehicles
Maintainance of dwelling
Maintainance of vehicles
Non-Durables
Food, beverages, tob.
Household durable w.o. appliances
Clothing
Household appliances
Other manufacturing
Other housing
Health
Other services
Energy/Energy relevant
Air Transport
Other public transport
Coal, lignite
Crude petroleum
Natural gas
Coke
Refined petroleum products
Electricity
Other electricity
Gas
Steam and air conditioning

Finally, the third nest comprises the level of single goods and services, as shown in Table A.3.

Table A.2: Goods and services of the consumption model

NACE/CPA	
01	Products of agriculture, hunting and related services
02	Products of forestry, logging and related services
03	Fish and fishing products
08-09	Other mining a. quarrying prod.; mining support services
10	Food products
11-12	Beverages, Tobacco products
13	Textiles
14	Wearing apparel
15	Leather and related products
16	Wood and products of wood and cork
17	Paper and paper products
18	Printing and recording services
20	Chemicals and chemical products
21	Basic pharmaceutical products and preparations
22	Rubber and plastic products
23	Other non-metallic mineral products
241 - 243	Iron & Steel
244 - 245	Other basic metals
25	Fabricated metal products, exc. machinery and equipment
26	Computer, electronic and optical products
27	Electrical equipment
28	Machinery and equipment n.e.c.
29	Motor vehicles, trailers and semi-trailers
30	Other transport equipment
31	Furniture
32	Other manufactured goods
33	Repair a.installation services of machinery a.equipment
36	Natural water; water treatment and supply services
37-39	Sewerage, waste management a. remediation services

Table A.3: continued

NACE/CPA	
41	Buildings and building construction works
42	Constructions a.construction works for civil engineering
43	Specialised construction works
45	Wholesale- a. retail trade, repair of motor vehicles
46	Wholesale trade, exc. o.motor vehicles a. -cycles
47	Retail trade, exc. o.motor vehicles a. -cycles
49	Land transport services a. transport services via pipelines
50	Water transport services
51	Air transport services
52	Warehousing and support services for transportation
53	Postal and courier services
55-56	Accommod. services; food a.beverage serving services
58	Publishing activities
59	Audiovisual services
60	Programming and broadcasting services
61	Telecommunications services
62-63	Information technology serv., communication services
64	Financial services
65	Insurance, reinsurance and pension funding services
66	Services auxiliary to financial a. insurance services
68	Real estate services
69	Legal and accounting services
70	Serv. of head offices; management consulting services
71	Architectural and engineering services
72	Scientific research and development services
73	Advertising and market research services
74-75	Other prof., scientific, technical serv.; veterinary services
77	Rental and leasing services
78	Employment services
79	Travel agency, tour operator and related services
80-82	Other business support services
84	Public administration, defence, social security services
85	Education services
86	Human health services
87-88	Residential care services, social work services
90	Creative, arts and entertainment services
91	Library, archive, museum and other cultural services
92	Gambling and betting services
93	Sporting services, amusement and recreation services
94	Services furnished by membership organisations
95	Repair services of computers, pers. a. household goods
96	Other personal services
97	Services of households as employers of dom. personnel