Appendix to "Why Has Durable Goods Spending Been So Strong during the COVID-19 Pandemic?" 2021. Kristen Tauber and Willem Van Zandweghe. Federal Reserve Bank of Cleveland, *Economic Commentary*, 2021-16

This appendix first describes the panel regression model used to estimate the MPCs in table 1. It then derives the formula for aggregating the predictions of states' durable goods spending growth in 2020, which underlies the results in table 2.

Panel regression model of durable goods spending

The panel regression model can be represented mathematically as:

$$c_{s,t} = \beta y_{s,t} + \mu_s + \nu_t + u_{s,t} \quad \text{(A.1)}$$

where $c_{s,t}$ and $y_{s,t}$ are, respectively, durable goods PCE growth and personal income growth in state $s = 1, \ldots, n$ and year $t = 1, \ldots, T$, μ_s denote the state fixed effects, ν_t denote the year fixed effects, and $u_{s,t}$ is a residual that captures any variation not accounted for by the variables in the model. The coefficient β denotes the MPC.

The coefficient β can be estimated by rewriting the model (A.1) in terms of deviations from state- and time-specific means as

$$c_{s,t} - \bar{c}_s - \bar{c}_t + \bar{c} = \beta\left(y_{s,t} - \bar{y}_s - \bar{y}_t + \bar{y}\right) + e_{s,t}, \quad \text{(A.2)}$$

where $\bar{x}_s = (1/T)\sum_{t=1}^{T} x_{s,t}$ is the state-specific mean of a variable $x_{s,t}$, for x=c, y, u; $\bar{x}_t = (1/n)\sum_{s=1}^{n} x_{s,t}$ is the time-specific mean, $\bar{x} = \left(1/(nT)\right)\sum_{t=1}^{T}\sum_{s=1}^{n} x_{s,t}$ is the sample mean and $e_{s,t} = u_{s,t} - \bar{u}_s - \bar{u}_t$. This so-called within transformation of the fixed effects model (A.1) demonstrates that the model controls for permanent differences between states and for economy-wide changes over time. Thus, the data used for estimating the MPC consist of the state-level variation in durable goods PCE growth and income growth, as macroeconomic variation ($\bar{x}_t$) and state-level trends ($\bar{x}_s$) are removed. The sample means $\bar{x}$ are added to keep the mean of the transformed variables equal to zero, since there is no constant term in the model. We estimate the transformed model (A.2) by ordinary least squares to obtain estimates of the MPC for durable goods PCE and its three major components (PCE for motor vehicles, furniture and appliances, and recreational goods).

Aggregation of state-level durable goods spending growth rates

Equation (A.2) can be rearranged to produce the prediction for each state's durable goods spending growth given by equation (1), noting that the predicted residual is $\hat{e}_{s,2020} = 0$.

To obtain a prediction for economy-wide durable goods spending growth, the predictions for each state must be aggregated. Each state's weight in this aggregation is given by $\tilde{\omega}_{s,t} \equiv \left[\left(P_{s,t}Y_{s,t-1}\right)/\left(P_tY_{t-1}\right)\right]\left[\left(N_{s,t}/N_{s,t-1}\right)/\left(N_t/N_{t-1}\right)\right]$, where $P_{s,t}$, $Y_{s,t}$, and $N_{s,t}$ denote the output price level, real personal income, and population of state s in period t, respectively, and P_t, Y_t,

and N_t are their aggregate counterparts. To see this, note that for any good or service, aggregate nominal PCE equals the sum of the states' nominal PCE: $P_t Y_t = \sum_s P_{s,t} Y_{s,t}$. Then, dividing each side by past nominal PCE $P_{t-1} Y_{t-1}$ and current population growth N_t / N_{t-1} yields the aggregation of states' real per capita growth rates: $(Y_t/N_t)/(Y_{t-1}/N_{t-1}) = \sum_s \widetilde{\omega}_{s,t} \left(Y_{s,t}/N_{s,t}\right)/\left(Y_{s,t-1}/N_{s,t-1}\right)$.

We cannot calculate the exact weights for this aggregation because of data limitations but approximate them by the product of the state's share in nominal PCE last period and its relative population growth rate, denoted by $\omega_{s,t}$. Specifically, $\omega_{s,t} \equiv \left[\left(P_{s,t-1} Y_{s,t-1}\right)/(P_{t-1} Y_{t-1})\right]\left[\left(N_{s,t}/N_{s,t-1}\right)/(N_t/N_{t-1})\right] = (P_t/P_{t-1})/\left(P_{s,t}/P_{s,t-1}\right)\widetilde{\omega}_{s,t}$. The approximate weights $\omega_{s,t}$ yield an aggregate growth rate that is quite accurate based on a comparison of the available state and aggregate data. We compared the published aggregate growth rates with our approximated counterparts in the sample from 1997 to 2019 and found that the mean absolute errors for the growth in PCE on durable goods, motor vehicles, furniture and appliances, and recreational goods are each less than 0.1 percentage point. We could not verify the accuracy of the approximate aggregation for 2020, since state durable goods PCE figures for 2020 were not yet released at the time of publication.

Having calculated the state weights, we apply them to equation (1) in order to aggregate durable goods PCE for all the states:

$$\sum_{s=1}^{n} \omega_{s,2020} \hat{c}_{s,2020} = \sum_{s=1}^{n} \omega_{s,2020} [\bar{c}_s - \bar{c} - \beta(\bar{y}_s - \bar{y})] + \beta \sum_{s=1}^{n} \omega_{s,2020} y_{s,2020} + \sum_{s=1}^{n} \omega_{s,2020} (\bar{c}_{2020} - \beta \bar{y}_{2020}) \quad \text{(A.3)}$$

The three terms on the right-hand side of equation (A.3) denote the contributions of long-run factors, income growth, and economy-wide factors specific to 2020, respectively, to the predicted aggregate per capita durable goods spending growth. The contributions, calculated using the estimated MPC and the aggregate durable goods spending and personal income data for 2020, are displayed in table 2.