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ABSTRACT

We study the effects of uncertainty on time use and their macroeconomic implications. Employing data from the American Time Use Survey and the Bureau of Labor Statistics, we document that heightened uncertainty increases housework and reduces market work hours, mildly impacting leisure. We then propose a model that quantitatively accounts for these estimates. We show that substitution between market and housework provides self-insurance to households, weakening precautionary savings. However, it also reduces aggregate demand, ultimately amplifying uncertainty's recessionary impact. Time reallocation can lead to higher inflation, particularly when uncertainty couples with policies redirecting time use towards housework (e.g., lockdown restrictions).

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1 Introduction

In the past fifteen years, a vast literature has analyzed the effects of aggregate economic uncertainty. A central message of this research is that uncertainty shocks are recessionary and create income risk for households. In turn, households' behavior plays an important role in propagating the macroeconomic effects of uncertainty (e.g., Basu and Bundick, 2017). Akin to the paradox of thrift (going back to DeMandeville, 1714, and Keynes, 1936), a rise in desired savings due to precaution contributes to lowering aggregate demand and output.

While the literature emphasizes the consequences of financial constraints and market incompleteness for households' precautionary behavior, decisions about time use have been thus far overlooked. How does aggregate uncertainty affect time allocation among market work, home production and leisure? Does time reallocation mitigate the shortfall in consumption that income risk brings about? Does it affect the aggregate transmission of uncertainty shocks? We address these questions both empirically and theoretically. In so doing, our analysis also sheds light on the macroeconomic effects of housework during the Covid-19 pandemic. This unprecedented event led to substantial shifts in time use and spending patterns amid heightened uncertainty, reflecting government policies and fear of contagion.

In the first part of the paper, we use data from the American Time Use Survey (ATUS) and the Bureau of Labor Statistics (BLS) to estimate the response of housework and leisure time to an increase in uncertainty. ATUS provides nationally representative estimates of how Americans spend their time. While the survey gathers high-frequency data on the full range of nonmarket activities, the relatively short sample prevents the use of standard detrending methods to control for the secular trends in housework and leisure.¹ To overcome this issue, we propose an approach that combines insights from the very influential work of Aguiar et al. (2013)—AHK henceforth—and Mukoyama et al. (2018). Building on AHK, we first leverage cross-state variation in time use to estimate how market hours are reallocated to other activities (e.g., home production, leisure, etc.) over the business cycle—what we refer to as cyclical substitution rates. While AHK provides estimates for a specific historical episode (the Great Recession), our investigation centers on whether time substitution varies throughout the cycle, particularly during periods of heightened aggregate

¹Aggregate data on home production are available for a long period only at a very low frequency and document secular trends that began in the 1960s. The ATUS starts in 2003.

uncertainty. We find that substitution rates are similar in periods of high and low uncertainty and, more generally, are independent of business cycle conditions. An implication of these results is that variation in housework and leisure is ultimately proportional to changes in market hours worked.

To quantify the impact of uncertainty, we finally combine the estimated substitution rates with data on hours worked from the Bureau of Labor Statistics (BLS), constructing longer time series for home production and leisure.² In this regard, our approach is conceptually similar to Mukoyama et al. (2018), who combine information from the ATUS and the Current Population Survey (CPS) to construct a measure of search effort. Using these novel series, we estimate local projections to identify the response of market hours, housework, and leisure to an increase in uncertainty. Following the standard practice in the literature we use the monthly Chicago Board Options Exchange Volatility Index (VIX) and identify variation in uncertainty that is plausibly exogenous to first-moment shocks by imposing conventional contemporaneous exclusion restrictions.³ Consistent with previous studies (e.g., Basu and Bundick (2017)), higher uncertainty reduces market hours worked. In addition, we document that uncertainty increases housework, with modest effects on leisure.

In the second part of the paper, we embed a benchmark housework model in an otherwise-standard business cycle model that features both first- and second-moment shocks to interpret the empirical findings. Following the seminal work of Benhabib et al. (1991), we assume that households can employ time to produce goods that are non-tradable on the market. Households also enjoy the consumption of market goods and leisure. Aside from home production, the model follows Basu and Bundick (2017), including sticky prices, endogenous capital accumulation, and shocks to preference and technology. Similarly to Born and Pfeifer (2014) and Fernandez-Villaverde et al. (2015), this framework has become a workhorse model for studying the aggregate transmission of uncertainty.

Using a standard and empirically plausible parametrization, we first show the model closely matches the empirical estimates: Higher uncertainty leads to a decline in hours worked (and GDP), with most of the lost market hours being reallocated to home production. We then use the model to study and quantify the contribution of time use allocation for the aggregate transmission of uncertainty.

We demonstrate that time reallocation provides an additional insurance margin to households,

²For robustness, we also consider CPS data for hours worked on the market. The advantage of BLS data is that they are available for a longer time period.

³The VIX captures the expected volatility of the Standard and Poor's 100 stock index over the next 30 days.

weakening precautionary savings and labor supply. We illustrate this result in a simple, two-period partial-equilibrium version of the model that singles out the effect of labor income uncertainty on households’ savings, consumption, and time use decisions, for given relative prices. The ability to reallocate market hours to home production allows households to insure against consumption risk, by compensating a given shortfall in market expenditures with home-produced goods. It is thus this substitution that makes housework an effective self-insurance tool when shocks to labor income materialize.

As time reallocation mitigates precautionary motives, one might expect it to dampen uncertainty’s contractionary effects. However, ultimately, time reallocation amplifies the aggregate output decline when prices adjust, i.e., in general equilibrium. In our benchmark parameterization, time reallocation towards housework explains approximately one-third of the output decline following a one-standard-deviation increase in the model-implied VIX. Notably, this larger output contraction is not mirrored by a correspondingly larger decline in prices. The intuition is the following. In addition to weakening precautionary motives, time reallocation also lowers aggregate demand by inducing complementarity between market-hours worked and consumption expenditures.⁴ That is, when the real wage and thus labor income falls, households substitute market goods with home production. Ultimately, this substitution, which would not be feasible absent home production, increases the aggregate demand elasticity to uncertainty and explains the more severe recession. Despite the larger contraction in consumption expenditures, the increase in housework—which remains unmeasured in national accounts data—results in a higher level of households’ welfare-relevant consumption. Moreover, the substitution of market work with housework puts upward pressure on real wages, which translates to higher marginal costs and inflation, all else being equal.

Lastly, to delve deeper into the role of time use allocation in output and price dynamics, we investigate how policies inducing time reallocation can interact with uncertainty. These policies were introduced in response to the outbreak of the COVID-19 pandemic.⁵ Our framework allows us to capture in reduced form the reallocation towards housework stemming from the closure of contact-intensive sectors and the subsequent lockdowns. We demonstrate that such policies exacerbate the contraction of aggregate demand due to heightened uncertainty. Moreover, they moderate its deflationary impact to the point of even becoming inflationary, depending on their

⁴This finding relates to studies where such complementarity is hardwired into preferences to explain a range of different macroeconomic outcomes (e.g., Bilbiie (2011), Christiano et al. (2011), Hall (2009), Miyamoto and Nguyen (2017), Monacelli and Perotti (2010), Nakamura and Steinsson (2014)).

⁵Castelnuovo (2022) provides an excellent survey of the literature on the macroeconomic effects of uncertainty before and during COVID-19.

stringency and duration. A caveat to these results is that we abstract from the economic benefits of limiting contagion, and the wide range of extraordinary monetary and fiscal policies that were implemented at the time.

Related Literature

Our paper contributes to two main strands of the literature. First, we contribute to the literature that analyzes the aggregate effects of uncertainty.⁶ We break new ground by presenting novel empirical results about the effects of uncertainty on time use—market work, nonmarket work, and leisure time. Additionally, we demonstrate how time use influences precautionary behavior and aggregate demand, which, in turn, play a central role in the propagation of uncertainty. Our results underscore the quantitative importance of time use adjustment for the contractionary effects of uncertainty. Furthermore, they show that policies promoting substitution between market hours worked and home production can exacerbate the contractionary effects of uncertainty while leading to higher inflation.

Our second contribution is to the literature studying home production and its macroeconomic implications. Benhabib et al. (1991) and Greenwood and Hercowitz (1991) emphasized the importance of accounting for households’ time allocation to explain a number of macroeconomic facts. For example, substitution between market hours worked and housework improves the explanatory power of fluctuations in total factor productivity for understanding cyclical variation in output. These seminal contributions spurred further research. McGrattan et al. (1997) estimate the model in Benhabib et al. (1991) to analyze the role of home production in shaping the households’ response to tax changes; Aruoba et al. (2016) document how interest rates and inflation affect households’ incentives to reallocate labor and capital between market and home activities; and Gnocchi et al. (2016) show the importance of home production in accounting for the magnitude of fiscal multipliers. In the context of an open-economy model, Karabarbounis (2014) show how the feedback between the home and market sectors can help explain several stylized facts studied by international macroeconomics. Parallel to, and as a complement to those contributions, a series of papers focused on documenting a number of facts related to time allocation, from its secular trends (see e.g., Aguiar and Hurst (2016), Ramey and Francis (2009), Ramey (2009)) to the reallocation of lost market hours during the great recession (Aguiar et al. (2013)), or during the pandemic-induced recession

⁶For an excellent review of the literature on uncertainty shocks and business cycle research, see Fernandez-Villaverde and Guerron-Quintana, 2020.

(Leukhina and Yu (2022)). Our contribution to this literature is threefold. First, we construct measures of cyclical variation in housework and leisure and document the hitherto-unexplored role of uncertainty in time use dynamics. Second, we demonstrate that a benchmark housework model, embedded in an otherwise-standard New Keynesian model, can account for time use dynamics and the comovement of macro variables in response to second-moment shocks. Third, we illustrate how households' time-use decisions affect the transmission of uncertainty to market variables.

2 Time Use and Uncertainty in the Data

This section studies how time use responds to increased uncertainty. Thus far, the dearth of comprehensive data has prevented a systematic analysis of this issue. An important limitation is that aggregate data on time use are available for a long period only at a very low frequency. Since the early 2000s, an alternative source is the ATUS database, a time-use survey that measures the amount of time people spend on various activities, including work, leisure, and household activities. ATUS data provide time-use information at business-cycle frequency. However, the relatively short sample of the data, combined with the well-documented secular trends in aggregate nonmarket work time and leisure, still preclude ordinary time series analysis. The short sample only includes one recession and two booms, which prevents the application of standard detrending methods, as already pointed out by AHK. Thus, to identify the effects of uncertainty on time use, researchers can exploit only cross-sectional variation in uncertainty exposure, which by design measures relative effects.

The first contribution of our paper is to construct measures of cyclical variation in nonmarket work and leisure. Our approach uses ATUS and BLS data, combining insights from AHK and Mukoyama et al. (2018). The approach can be summarized as follows. Start by noticing that the cyclical variation in aggregate market hours allocated to activity j can be expressed as:

$$\Delta H_t^j = \beta_t^j \Delta H_t^{market}, \quad (1)$$

where ΔH_t^{market} denotes the change in aggregate market hours, and β_t^j represents the fraction of market hours reallocated to activity j for cyclical reasons at time t . Equation (1) defines β_t^j as the cyclical substitution rate of activity j and generalizes the decomposition in AHK by allowing for potential time variation. Equation (1) provides only a statistical decomposition, implying that β_t^j is an accounting device and not a structural parameter.

We estimate the cyclical substitution between market work and other time-use categories building on the methodology proposed by AHK. Next, we use the estimated substitution rates to infer cyclical variation in housework and leisure using (1). Finally, we estimate local projections to identify the effects of uncertainty on market hours, housework, and leisure.

Cyclical Variation in Time Use

We use data from the 2003–2019 waves of the ATUS, restricting the sample to working-age respondents (between age 15-65). The ATUS is conducted by the BLS, and individuals in the sample are drawn from the outgoing rotation group of the CPS.⁷ We further complement our analysis with data from the American Heritage Time Use Study (AHTUS) for the years 1993, 1995, and 1998. Following AHK, we segment the allocation of time into broad time-use categories that are mutually exclusive and that sum to the individual’s entire time endowment. In our regressions, we select a subset of those categories: market work, nonmarket work, and leisure.⁸ Market work includes all time spent working in the market sector, including commuting to and from work, and time spent on work-related activities. Nonmarket work includes core home production (e.g., cooking, cleaning, or doing laundry), activities related to home ownership (such as household repairs and gardening), obtaining goods and services (including grocery shopping, going to the bank, and online shopping), and care of other adults (e.g., preparing meals and shopping for other adults, and transporting other adults to doctors’ offices). Finally, leisure includes time spent watching TV, socializing, exercising, reading, sleeping, eating, time spent on sports, entertainment, hobbies and personal care.

There is ample evidence that nonmarket work has been declining over time, while leisure time has been increasing (see, e.g., Aguiar and Hurst (2016), Ramey and Francis (2009), Ramey (2009)). However, the relatively short time frame of the sample precludes the use of standard detrending methods. We follow AHK and exploit the variation of cross-state business cycles to remove these low-frequency trends in time use when estimating substitution rates.⁹ Hence, we construct average state-level time use across individual respondents (i.e., we treat the data as a pseudo panel).

To infer how changes in market hours worked affect different time use categories, we consider three alternative state-level specifications. The first specification constrains β_t^j to be constant across

⁷ATUS data is a pooled cross section, as each respondent is interviewed once.

⁸AHK also include other income-generating activities (i.e., outside the formal sector), such as job search, child care, and other activities such as education. Hence, time spent on job search and other income-generating activities are not included in market work.

⁹This approach hinges on the absence of state-specific low-frequency trends in time use, and on existing variation of changes in market work hours across states, as shown by AHK. Tables 1 and 2 in Appendix A present descriptive statistics for changes in state-level market work hours.

time, following AHK. The second specification relaxes this assumption and allows for time variation in β_t^j . The third specification addresses whether β_t^j differs at times of high and low uncertainty. Across these exercises, the main finding is that the substitution rate between market hours and housework or leisure is stable over time and across regimes of low and high uncertainty.

Constant Substitution

Our first specification re-estimates the main regression in AHK using ATUS data from 2003–2019:

$$\Delta\tau_{s,t}^j = \alpha^j - \beta^j \Delta\tau_{s,t}^{market} + \gamma \Delta X_{s,t} + \varepsilon_{s,t}^j, \quad (2)$$

where $\Delta\tau_{st}^j$ is the change in hours per week spent on time use category j for the average individual in state s between period $t - 1$ and t . $\Delta\tau_{st}^{market}$ is the change in market hours worked for the average individual in state s between period $t - 1$ and t . $\Delta X_{s,t}$ are demographic controls, to capture potentially time-varying state-level demographic composition.¹⁰ The coefficient of interest, β^j , measures the fraction of foregone market hours allocated to time-use category j . β^j is a simple accounting device that measures how activity j co-varies with market hours once aggregate trends (captured by the constant α^j) are controlled for. For brevity, below we refer to the β^j 's as reduced-form substitution rates, while it remains understood that such parameters bear no structural interpretation. We estimate equation (2) using weighted least squares, where states are weighted by their population.

The estimates in AHK—based on ATUS data from 2003–2010—remain largely unchanged when using nine additional years of ATUS data. Table 1 reports the estimated β^j for nonmarket work and leisure, when $\Delta\tau_{st}^j$ is defined as the difference in average time spent on activity j in state s from one non-overlapping two-year period to another.¹¹ A reduction of one hour per week in market work increases time spent on nonmarket work by 0.25 (vs. 0.28 in AHK), and time spent on leisure by 0.60 (vs. 0.52 in AHK). These estimates are robust to alternative definitions of the dependent variable, $\Delta\tau_{st}^j$, based on annual or quarterly state-level data, and when including state-level and/or time fixed effects (see Tables 3 and 4 in Appendix A).

¹⁰We include the same controls as AHK, i.e., the sample fraction of five age bins (18–27, 28–37, 38–47, 48–57, 58–65), four education bins (less than high school, high school, some college, BA/MA/PhD), the sample fraction that is male, black, married, and has at least one child.

¹¹As the ATUS weighting procedure does not guarantee that the sample is representative of the population in a given state, AHK average state-level data over two years to mitigate measurement error due to sampling variation. AHK use 2003–2010 ATUS data and thus have a total of 153 observations. Our estimation relies on 357 observations (51 states, 7 differences over two-year periods).

Time Use Category	$\hat{\beta}^j$ (1)	$\hat{\beta}_L^j$ (3)	$\hat{\beta}_H^j$ (3)	p-value $H_0 : \hat{\beta}_L^j = \hat{\beta}_H^j$
Nonmarket Work	0.25	0.25	0.22	0.26
Leisure	0.60	0.60	0.60	0.88

Table 1: Estimated cyclical substitution between market work and nonmarket work or leisure, from regression (2) and (4).

Time-Varying Substitution

It is conceivable that the substitution rate may have changed over time. To explore potential time-variation, we use a repeated cross-section that combines the available ATUS data from 2003–2019 with AHTUS data for the years 1993, 1995, and 1998 to estimate the following regression for each year t :

$$\Delta\tau_{s,t}^j = \alpha_t^j - \beta_t^j \times \Delta\tau_{s,t}^{market} + \gamma_t \Delta X_{s,t} + \varepsilon_{s,t}, \quad (3)$$

where $\Delta\tau_{s,t}^j$ is now defined as the year-over-year change in time use of activity j in state s .¹² We then test the null hypothesis $H_0 : \beta_t^j = \beta^j$, where β^j is the coefficient from equation (2) estimated over the entire sample. Table 5 in Appendix A reports the respective p-values. We do not find any statistically significant difference (at the 95% level) between β_t^j and β^j for any activity j (with the exception of leisure in the years 2009 and 2015). Thus, the data suggest that the estimated substitution rates are stable over time.

State-Dependence

Finally, we also consider the possibility that individuals who experience a reduction in work hours during times of heightened uncertainty may choose to allocate their time to different activities than they would in normal times. We therefore explore potential state-dependence of the substitution rates, an important issue given our interest in the effects of uncertainty on time use. We rely on two uncertainty measures, the state-level policy uncertainty index from Baker et al. (2022) that measures the level of uncertainty within a U.S. state stemming from local policy issues, and the VIX, a measure of aggregate uncertainty.

¹²AHTUS data is available for other years, but unfortunately only includes information on respondents' state of residence in 1993, 1995, and 1998. To estimate the substitution rate for 1995, the dependent variable is defined as $\Delta\tau_{s,95}^j = \tau_{s,1995}^j - \tau_{s,1993}^j$, and for 1998, we have $\Delta\tau_{s,98}^j = \tau_{s,1998}^j - \tau_{s,1995}^j$.

We estimate the following version of (2):

$$\Delta\tau_{s,t}^j = \alpha^j - \left[\beta_L^j (1 - \mathcal{I}_{s,t}) + \beta_H^j \mathcal{I}_{s,t} \right] \times \Delta\tau_{s,t}^{market} + \gamma \Delta X_{s,t} + \varepsilon_{s,t}, \quad (4)$$

where $\mathcal{I}_{s,t}$ is a dummy variable taking value one in periods where the state-level policy uncertainty index (or the VIX) is one standard deviation above its mean and zero otherwise (when using the VIX, $\mathcal{I}_{s,t}$ is of course identical across states). To identify state-dependent substitution rates using cross-state variation, there must be sufficient variation in state-level market-hour changes during high and low uncertainty episodes. Table 2 presents descriptive statistics confirming that there is such variation. Figures 1 and 2 further show that both uncertainty measures display substantial variation over the sample both in booms and recessions, and they thus convey additional information above and beyond the state of the business cycle.

	Pooled Sample	High Aggregate Uncertainty	Low Aggregate Uncertainty	High State Policy Uncertainty	Low State Policy Uncertainty
Mean	0.002	-0.48	0.007	0.46	-0.18
Standard Deviation	10.28	10.01	10.32	10.55	10.17
10th Percentile	-11.38	-12.12	-11.28	-11.43	-11.26
25th Percentile	-5.42	-5.43	-5.42	-5.31	-5.46
50th Percentile	0.03	-0.33	0.03	0.76	-0.20
75th Percentile	5.22	5.00	5.30	5.71	5.06
90th Percentile	11.11	10.42	11.21	11.47	11.04
Percent Negative Changes	49.87	52.21	49.55	49.58	49.98

Table 2: Summary statistics of quarterly year-over-year changes in market work hours per week and state ($\Delta\tau_{st}^{market}$). Observations are weighted with each state’s population. Episodes of high aggregate uncertainty represent quarters where the VIX is one standard deviation above its mean ($\mathcal{I}_t = 1$), and episodes of high state-level policy uncertainty capture quarters where this uncertainty measure is one standard deviation above its mean ($\mathcal{I}_{s,t} = 1$).

The estimated coefficients of equation (4) using state-level policy uncertainty, reported in Table 1, suggest that the substitution rates are stable across times of high vs. low uncertainty. The respective null hypothesis ($H_0 : \hat{\beta}_L^j = \hat{\beta}_H^j$) cannot be rejected (at the 95% level) for both nonmarket work and leisure. Also in this case, the data thus suggest that the estimated coefficients are stable across regimes of low and high uncertainty.¹³

¹³The estimated coefficients and p-values using the dummy variable based on the VIX are close to the ones reported in Table 1.

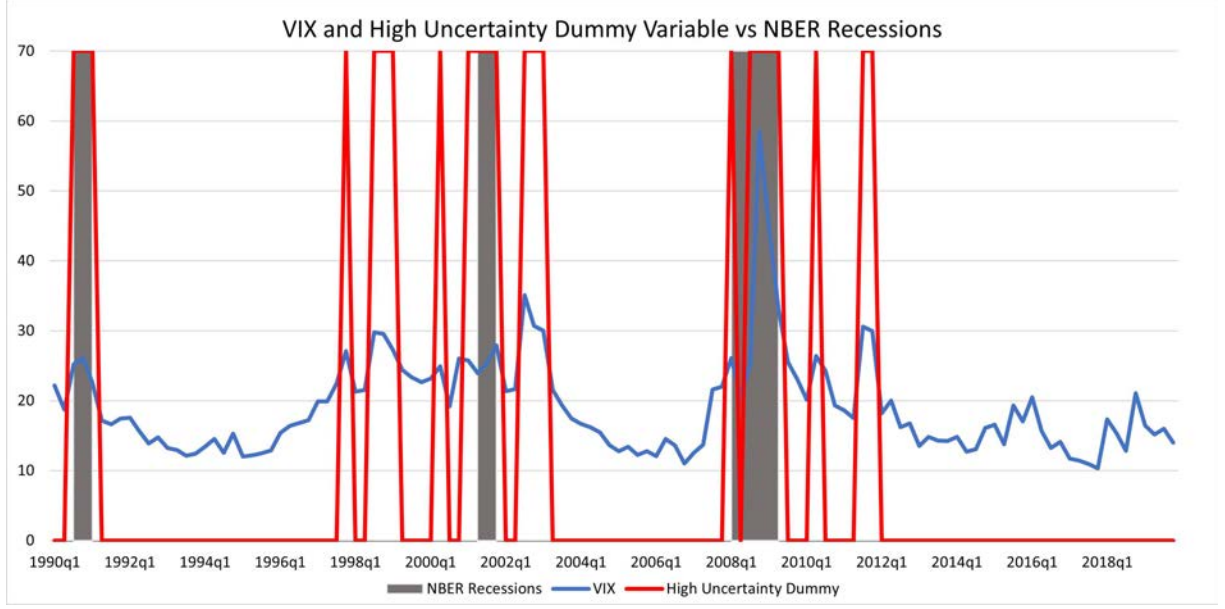


Figure 1: Variation in aggregate uncertainty measure (VIX) outside NBER recession.

Time Series for Time Use

We can now construct cyclical series for housework and leisure using equation (1). Given the time and state independence of the estimated substitution rates, our benchmark time-use series are constructed with β^j from (2) estimated over the entire ATUS data from 2003–2019. For robustness, we also construct alternative series based on annual estimates for β_t^j as per (3).

We compute the implied changes in hours of a given activity, j , by combining the estimated substitution rates, β^j , with observed changes in market hours:

$$\Delta H_t^j = \hat{\beta}^j \Delta H_t^{market}.$$

For market hours, H_t^{market} , we use data from the BLS. We focus on the period 1990:Q1–2019:Q4, starting with the earliest available observation for the VIX.¹⁴ We recover H_t^j using the average time-use from ATUS as initial condition. The time-use series capture the cyclical variation in time use of activity j , up to measurement error.¹⁵ Our exercise is similar in spirit to Mukoyama et al.

¹⁴We use the series “Aggregate Hours: Nonfarm Payrolls”. Using BLS data has two advantages over the alternative ATUS or CPS series. First, as already discussed, the ATUS only started in 2003. Second, the CPS series “Actual Hours Worked at the Main Job Last Week” (which starts in 1994) is rarely used in the business cycle literature we relate to. Our results are robust to using this alternative series.

¹⁵The aggregate state of the economy, captured by aggregate market hours or unemployment, does not have a significant explanatory power for individuals’ housework when their market hours are controlled for (see Appendix A). Consistent with AHK, this finding implies that, at business cycle frequency, most of the variation in housework is due to substitution with market hours (and not with leisure). This is consistent with the results in Nevo and

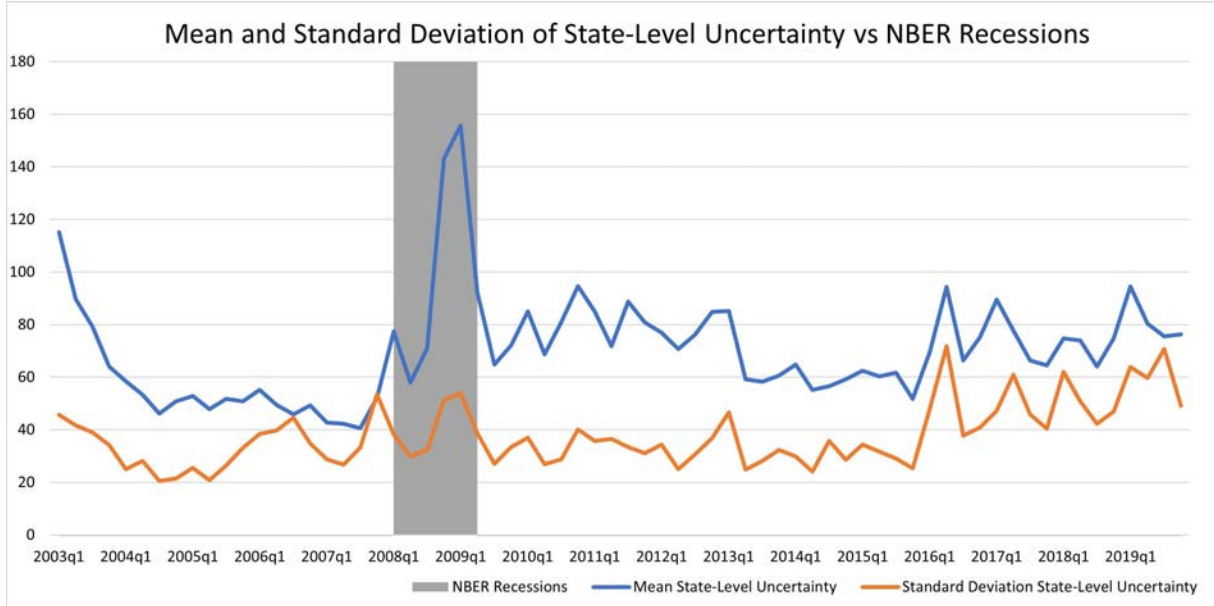


Figure 2: Mean and standard deviation in state-level policy uncertainty measure.

(2018), who combine information from the ATUS and the CPS to construct a measure of search effort.

Response of Time Use to Uncertainty

We are finally ready to estimate the effects of uncertainty on time use. Following standard practice in the literature, our benchmark measure of uncertainty is the VIX, which measures the expected volatility of the Standard and Poor’s 100 stock index over the next 30 days.

We first identify “uncertainty shocks,” i.e., variation in uncertainty plausibly exogenous to first-moment shocks. We then use the identified shocks to estimate local projections. Since Jordà (2005), local projections have become a popular and well-established tool to estimate impulse response functions in macroeconomics. The approach consists of running a sequence of predictive regressions of a variable of interest on a structural shock for different prediction horizons. Thus, local projections construct impulse responses as a direct multi-step forecasting regression, providing a flexible and parsimonious approach that does not impose (potentially inappropriate) dynamic restrictions.

Following the literature, we identify exogenous uncertainty shocks by purging variation in the VIX that is an endogenous response to first-moment shocks. As in Basu and Bundick (2017),

Wong (2019), that home production shocks were not the driving force behind the decline in market expenditures and increase in time spent on nonmarket work between 2008–2010.

we assume that uncertainty shocks can immediately impact macroeconomic variables, but non-uncertainty shocks do not affect the implied stock market volatility on impact—the theoretical model of the next section supports this identification strategy. Under these assumptions, we can identify uncertainty shocks as the estimated residual (μ_t^{vix}) from the following uni-variate regression:

$$vix_t = \alpha + \sum_{i=1}^p \phi_i^{vix} vix_{t-i} + \sum_{i=1}^p \phi_i^{ip} \Delta Y_{t-i} + \sum_{i=1}^p \phi_i^n \Delta H_{t-i} + \sum_{i=1}^p \phi_i^{oil} oil_{t-i} + \sum_{i=1}^p \phi_i^{ffr} ffr_{t-i} + \mu_t^{vix}, \quad (5)$$

where vix_t denotes the VIX, ΔY_t is the log-difference in real GDP, ΔH_t is the log-difference in hours worked, oil_t is the level of crude oil prices, and ffr_t is the federal funds rate. In Appendix A, we show that our results are robust to including the contemporaneous values of macroeconomic variables as controls in equation (5). This alternative specification embeds a different identifying assumption: innovations to the VIX do not affect contemporaneously real economic activity, as in Bloom (2009).

We use the estimated residual $\hat{\mu}_t^{vix}$ to identify time-use dynamics following an uncertainty shock. Specifically, we estimate the following instrumental variable local projections (LP-IV):

$$\log H_{t+\kappa}^j - \log H_{t-1}^j = \delta_\kappa + \gamma_\kappa \widehat{vix}_t + \sum_{i=1}^p \phi_{vix} vix_{t-i} + \sum_{i=1}^p \phi_{hj} \log H_{t-i}^j + \varepsilon_t^j \quad (6)$$

for $\kappa = 0, 1, 2, \dots$, where $\widehat{vix}_t$ are the fitted values from regressing the VIX on our instrument $\hat{\mu}_t^{vix}$ —we instrument rather than projecting directly $\hat{\mu}_t^{vix}$ acknowledging for estimation uncertainty around $\hat{\mu}_t^{vix}$.¹⁶ Figure 3 plots the estimated dynamics of market hours, nonmarket hours and leisure time in response to a one-standard deviation uncertainty shock—increasing the VIX by 31%.¹⁷ The uncertainty shock generates a contraction in market hours (with a peak response of roughly -0.15 percent). In contrast, both nonmarket hours worked and leisure increase. The increase in nonmarket hours worked is roughly three times as much as the increase in leisure time. In Appendix A, we show these results are robust to considering two alternative measures of uncertainty constructed by Jurado et al. (2015). Appendix A further presents the responses of a set of macro variables (real GDP, market consumption, investment and the price level).

¹⁶The literature that estimates local projections using fiscal-policy shocks identified as in Blanchard and Perotti (2002) follows a similar approach. We set $p = 3$. The first-stage F-statistic is 115.34, with a p-value smaller than 0.001.

¹⁷In annualized percentage points, a one-standard deviation shock raises the level of the VIX to about 25.5%, from its unconditional average of about 19%.

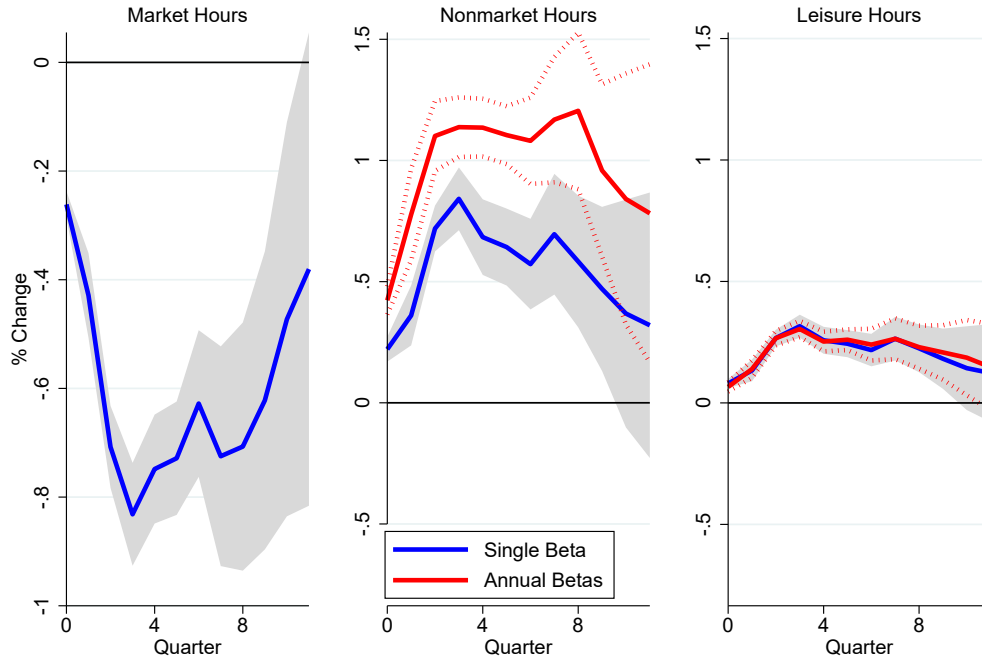


Figure 3: Estimated impulse responses and 90% confidence intervals for hours worked (from BLS), nonmarket hours and leisure time, conditional on a one-standard-deviation uncertainty shock, using data from 1990:Q1–2019:Q4. Nonmarket hours and leisure time series are constructed with β^j from (2) estimated over the entire ATUS data from 2003–2019 (blue line, labeled as 'average beta'), and alternatively with β_t^j from (3) estimated year by year (red line, labeled as 'annual betas').

3 Risk and Precaution in a Model of Home Production

Our goal is to build a model of housework that quantitatively accounts for the empirical results, and study time-use dynamics in response to uncertainty. To gain intuition, we start with a partial equilibrium model, which singles out the role of housework in shaping the transmission of uncertainty to market variables by muting its endogenous reaction to relative prices. To this end, we augment the standard two-period partial-equilibrium savings problem as in Ljungqvist and Sargent (2004) (p. 599), with home production modeled along the lines of Benhabib et al. (1991), where households self-produce home goods that can be consumed, but neither traded on the market nor stored. The choice of a finite time horizon with two periods is motivated by simplicity. We study the effect of uncertainty by examining the impact of labor income risk on the allocation of time and consumption, relative to a deterministic economy. In the next section, we present the fully-fledged general equilibrium model.

Households Problem

The time endowment is normalized to 1 and households can allocate it to market work, $h_{m,t}$, in exchange for a real wage w_t , or to housework, $h_{n,t}$. Home goods are produced according to the following linear technology,

$$C_{n,t} = h_{n,t}. \quad (7)$$

The residual time is enjoyed as leisure, l_t , so that

$$h_{m,t} + h_{n,t} + l_t = 1. \quad (8)$$

The flow budget constraint reads as

$$b_{t-1} + w_t h_{m,t} \geq C_{m,t} + r_t^{-1} b_t, \quad (9)$$

where $C_{m,t}$ denotes goods purchased on the market, b_{t-1} is a stock of non-contingent zero-coupon real bonds that pay one unit of the market good, and b_t is the stock of bonds that households can carry into the next period at a risk-free real return $r_t > 1$.

After aggregating market and home goods at a constant elasticity $1/(1 - b_1)$ into total con-

sumption, C_t ,

$$C_t = \left[\alpha_1 (C_{m,t})^{b_1} + (1 - \alpha_1) (C_{n,t})^{b_1} \right]^{\frac{1}{b_1}}, \quad \alpha_1 \in [0, 1] \quad b_1 < 1, \quad (10)$$

households' problem can be defined as choosing a state-contingent path for all variables so as to maximize utility

$$E_1 \sum_{t=1}^2 \beta^t U(C_t, l_t), \quad (11)$$

subject to constraints (7) to (10), for a given initial value of the stock of bonds b_0 . We assume that utility is increasing in both arguments and concave.

Optimality Conditions and Equilibrium

Let λ_t denote the marginal utility of market consumption:

$$\lambda_t = U_C(C_t, l_t) \alpha_1 \left(\frac{C_{m,t}}{C_t} \right)^{b_1-1}, \quad (12)$$

where U_C stands for the derivative of utility with respect to total consumption C_t . The solution to households' problem satisfies two intra-temporal conditions:

$$w_t = \frac{U_l(C_t, l_t)}{\lambda_t}, \quad (13)$$

$$1 = \frac{U_l(C_t, l_t)}{(1 - \alpha_1) U_C(C_t, l_t)} \left(\frac{C_{n,t}}{C_t} \right)^{1-b_1} \quad (14)$$

where U_l stands for the derivative of utility with respect to leisure. Equation (13) is the standard optimality condition solving for the allocation of time between leisure and market consumption. Equation (14) captures the additional housework-leisure tradeoff and equalizes the relative price of home consumption in terms of leisure, i.e., the marginal productivity of labor in the nonmarket sector, displayed on the left-hand side, to the corresponding marginal rate of substitution.

Finally, a conventional Euler equation and a terminal condition are required for the choice of bonds to be optimal inter-temporally:

$$\frac{\lambda_1}{r_1} = \beta E_1 \{ \lambda_2 \}, \quad b_2 = 0. \quad (15)$$

Optimality conditions (12)-(15) and constraints (7)-(10) define the equilibrium allocation, i.e., the optimal quantities C_t , $C_{m,t}$, $C_{n,t}$, $h_{m,t}$, $h_{n,t}$, l_t and b_t , as well as λ_t , for a given probability

distribution of prices w_t and r_t .

To ease interpretation of the results below, we further introduce Frisch functions, along the lines of Frisch (1959), Browning et al. (1985) and Hall (2009b). They are implicitly defined by equations (7), (8), (10), and (12)-(14), which are indeed sufficient to determine consumption and time use given w_t and λ_t . These functions disentangle intra-temporal and inter-temporal channels through which time allocation affects the transmission of uncertainty. In fact, the marginal utility of consumption embodies the entire forward-looking optimization of households, based on the expected life-time income profile. Hence, the elasticity of time use to the real wage for a constant value of λ_t singles out an intra-temporal channel, according to which households optimally respond to the market price of time, conditionally on having inter-temporally allocated lifetime income optimally. The elasticity to λ_t highlights instead an inter-temporal channel, according to which households reallocate time even though the contemporaneous relative price of time remains constant, because, for example, the volatility of future income has varied. Frisch functions are plotted and interpreted in the next section.

Results

To analyze the effects of uncertainty, we compare a deterministic economy with one that features labor income risk. In the riskless economy, prices are set at the deterministic steady state of the general equilibrium model discussed in the next section. In the economy with risk, for the first period the wage, w_1 , is known and equal to the level it takes in the deterministic economy. In the second period, it can instead take values w_L or w_H , $w_L < w_H$, with a 50 percent probability, and such that its expected value is equal to w_1 . We consider various mean-preserving spreads of the wage, with its percentage standard deviation spanning between 5 and 45 percent.

We need to parameterize the model in order to solve it numerically. Although we choose most of the parameters on an empirically relevant range, at this stage the analysis remains qualitative and exclusively aimed at discerning the main mechanisms at play. The quantitative assessment is postponed to the general equilibrium section. We specify the period utility function as

$$U(C_t, l_t) = \frac{\left(C_t^\eta l_t^{1-\eta}\right)^{1-\sigma} - 1}{1 - \sigma}, \quad (16)$$

and choose parameters as in the general equilibrium model.¹⁸ To highlight the role that substitution

¹⁸The initial stock of bonds b_0 is picked so that hours worked on the market and at home are roughly 0.33 and

between market hours and housework plays for the propagation of uncertainty, in our experiments, we either vary the elasticity of substitution between home and market goods, $1/(1 - b_1)$, or we compare the home production economy with one where housework is kept constant at the deterministic steady state of the home production model.¹⁹ In the latter case, for illustrative purposes, we fix $b_1 = 2/3$.

Precautionary Savings Channel (Inter-Temporal Substitution)

We first examine the overall effect of allowing for substitution between hours worked and housework on the conventional precautionary motives spurred by heightened uncertainty. We do so by computing (Figure 4) equilibrium bond holdings, market consumption, hours worked, housework and leisure in period 1 for different values of the standard deviation of the real wage in period 2, represented on the horizontal axis, and for different values of the elasticity of substitution between home and market goods. We compare the results with the economy where home production is held constant. The additional substitution margin attenuates precautionary motives by dampening the fall in market consumption and the rise in hours worked on the market that typically follow a spike in uncertainty, holding relative prices constant. For any level of the standard deviation of the real wage in period 2, both market consumption and market hours are indeed less responsive relative to the model without home production. This effect is bigger, the larger the substitutability between home and market goods. Notice that—holding prices constant—housework and leisure fall with uncertainty, moving in the opposite direction of hours worked. The intuition of the result can be explained with the fact that home goods, like market goods and leisure, are normal goods. Hence, in uncertain times, households, similar to the case of a negative shock to wealth, out of precaution prefer to reduce all goods and work more, so as to build a buffer against future expected volatility in market consumption. Time reallocation thus overall appears to be an effective self-insurance tool, mitigating, at given prices, the effects of uncertainty on the equilibrium allocation.

Complementarity Channel (Intra-Temporal Substitution)

To gain further economic intuition, Figure 5 plots Frisch functions for hours worked, housework, total consumption and market consumption in the models with and without home production where

0.19, respectively, which are the values used to calibrate the general equilibrium model later on. The implied value is $\eta = 0.5$.

¹⁹A variety of macro- and micro-economic studies suggest that substitutability between home and market goods falls in the empirically relevant range $[1.5; 4]$ as discussed in Gnocchi et al. (2016).

$b_1 = 2/3$. It is evident that when households can reallocate time freely, for a given value of λ , and therefore for motives that purely relate to the substitution induced by a change in the market price of time, housework negatively co-moves with the real wage. As an implication, market hours become more elastic. In other words, as the real wage and thus labor income falls, households compensate the shortfall in market expenditure with housework and an increase in the consumption of home goods, contributing to stabilizing fluctuations in total consumption. It is thus this substitution that makes housework an effective self-insurance tool when shocks to labor income materialize, as in period 2 of our model, attenuating precautionary motives in period 1. Together with better self-insurance to labor income shocks, and then lesser precautionary savings, home production also brings about a larger complementarity between market consumption and hours worked, which is highlighted in Figure 5, where the Frisch function for market consumption is plotted. Market consumption and hours worked are defined to be (Frisch) complements if consumption expenditure falls with the real wage, even if lifetime income is controlled for (i.e., for λ_t constant). As an implication due to complementarity with hours worked, market consumption becomes more responsive to the market price of time, which typically falls in recessions.

In sum, the partial-equilibrium analysis highlights that home production can affect the transmission of uncertainty shocks along two margins: an inter-temporal margin, which works through a wealth effect that leaves households better insured against income shocks and thus less inclined to save, and an intra-temporal margin, which works through a substitution effect that is due to the complementarity between market expenditure and market hours worked. The first channel is key for understanding whether home production is an effective margin to insure income risk. However, it is not enough to account for the results that obtain when relative prices endogenously react to uncertainty. In general equilibrium those two margins are both at play and, to the extent that uncertainty shocks are recessionary as in the data, they affect the transmission of the shock to market hours worked and consumption in opposite directions. What the net effect may be, and whether time substitution mitigates or exacerbates recessions triggered by uncertainty, depends on which of the two margins quantitatively prevails. This is a question that we explore in the analysis of the next section.²⁰

²⁰In general equilibrium, the endogenous response of relative prices, and thus the way the two channels combine, depends on various modelling assumptions, such as the one of price rigidity.

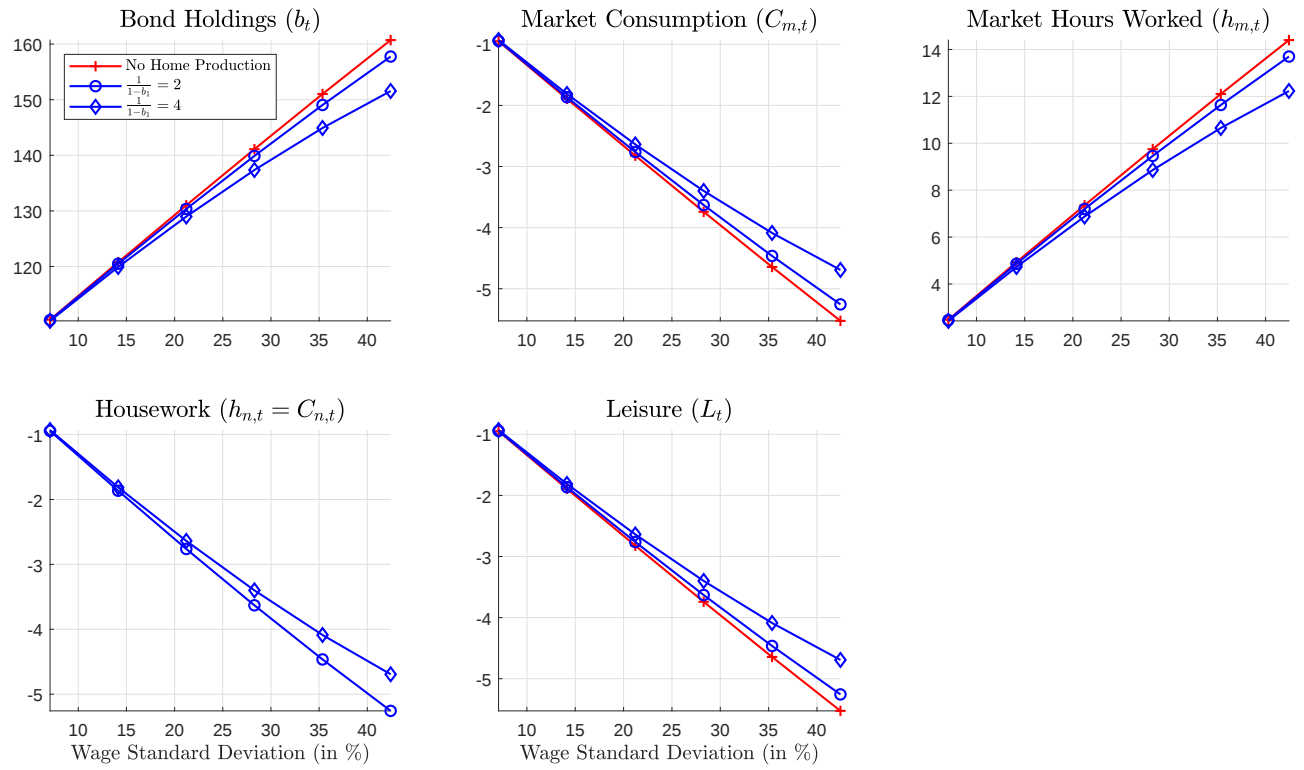


Figure 4: Percentage change in selected endogenous variables, relative to the model without uncertainty, as a function of the standard deviation of the real wage (in percentage points) and for selected values of the elasticity of substitutions between home and market goods.

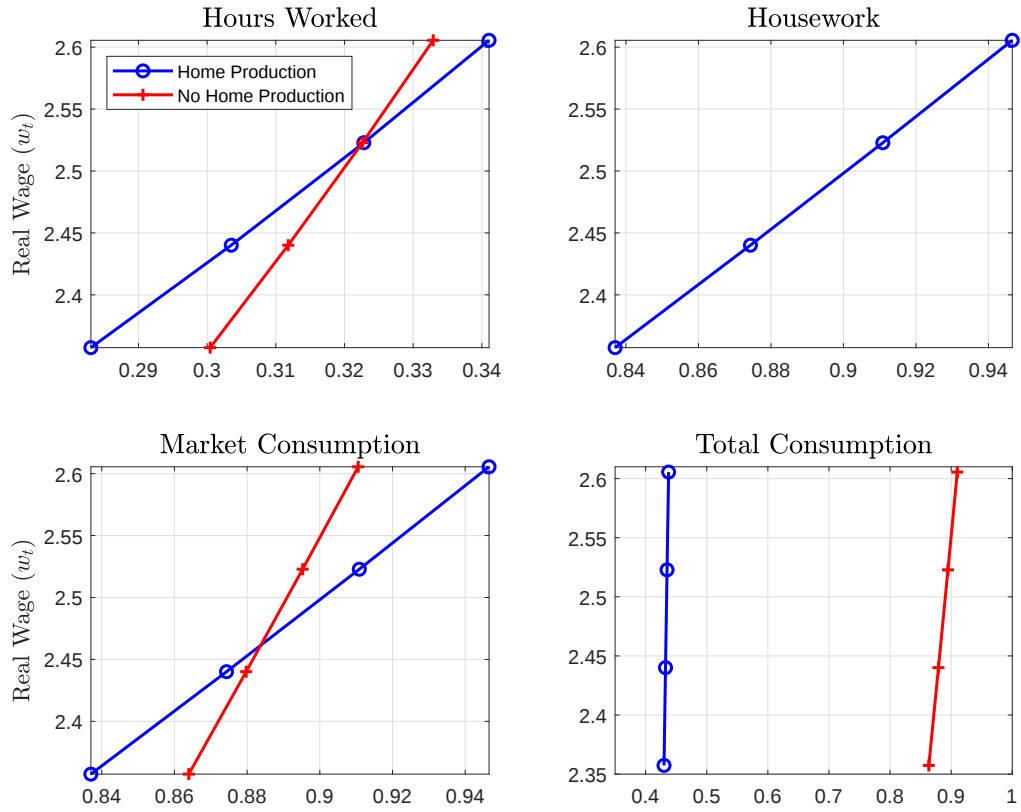


Figure 5: Frisch functions of selected endogenous variables against the real wage. The marginal utility of market consumption is held constant at its equilibrium value in period 1.

4 General Equilibrium Analysis

As discussed in the previous section, the partial-equilibrium model cannot discern whether time-use (and expenditures) reallocation ultimately results in a greater or lesser elasticity of aggregate output to uncertainty. To quantify the importance of time-use variation for the aggregate transmission of uncertainty, we embed the partial-equilibrium model of Section 3 into a dynamic stochastic general equilibrium model that features both first- and second-moment shocks. Aside from home production, the model follows Basu and Bundick (2017), a benchmark framework to study the macroeconomic effects of uncertainty shocks. As in their paper, we focus on uncertainty about future aggregate demand, assuming that exogenous discount rate shocks have a time-varying second moment. Thus, in contrast to the partial-equilibrium model, income uncertainty becomes an endogenous equilibrium outcome.

Model

Since the model structure follows Basu and Bundick (2017) closely, here we discuss only the model’s main insights. Appendix B contains all the equilibrium conditions. The model features optimizing households and firms, and output is demand-determined due to sticky prices. We resort to a cashless economy following Woodford (2003). As discussed by Basu and Bundick (2017), demand-determined output (at least over some time horizon) implies that uncertainty shocks cause shifts in the demand for goods and labor input. In turn, the contractionary effect of uncertainty on labor demand is central for the model to reproduce the recessionary effects observed in the data.²¹

Households

There is an infinitely lived representative household that maximizes lifetime utility over streams of consumption and leisure, C_t and l_t . We now assume Epstein–Zin preferences:

$$V_t = \max \left\{ a_t [U(C_t, l_t)]^{\frac{1-\sigma}{\theta_v}} + \beta (\mathbb{E}_t V_{t+1}^{1-\sigma})^{\frac{1}{\theta_v}} \right\}^{\frac{\theta_v}{1-\sigma}}, \quad (17)$$

²¹Countercyclical markups through sticky prices are also important to overcome the attenuation of the effects of uncertainty shocks observed in the standard neoclassical growth model (Basu and Bundick, 2017). Other mechanisms can deliver amplification and empirically-plausible macroeconomic comovement, including modeling several assets and agents’ heterogeneity (e.g., Fernandez-Villaverde et al., 2015) or ambiguity aversion (e.g., Ilut and Schneider, 2014).

where σ is the parameter controlling risk aversion over the consumption-leisure basket, ψ is the intertemporal elasticity of substitution, and $\theta_v = (1-\sigma)(1-1/\psi)^{-1}$.²² As in the partial-equilibrium model of Section 3, the period utility function is $U(C_t, l_t) = (C_t)^\eta (l_t)^{1-\eta}$, and the time endowment is normalized to 1. Equations (7) and (10) still determine preferences over market- and home-produced goods, $C_{m,t}$ and $C_{n,t}$, and the home production technology. Households' discount factor is subject to exogenous shocks via the stochastic process a_t .

Households receives labor income W_t for each unit of labor $h_{m,t}$ supplied to intermediate goods-producing firms. The representative household owns the intermediate goods firm and holds equity shares S_t and one-period riskless bonds B_t issued by the representative intermediate goods firm. Equity shares have a price P_t^E and pay dividends D_t^E for each share S_t . The gross one-period interest rate on the riskless bonds is R_t^R . The household allocates labor and financial income between consumption of market goods, $C_{m,t}$, and holdings of financial assets S_{t+1} and B_{t+1} to carry into the next period.

The household maximizes (17) subject to its intertemporal budget constraint each period:

$$C_{m,t} + \frac{P_t^E}{P_t} S_{t+1} + \frac{1}{R_t^R} B_{t+1} = \frac{W_t}{P_t} h_{m,t} + \left(\frac{D_t^E}{P_t} + \frac{P_t^E}{P_t} \right) S_t + B_t,$$

where P_t is the price index of the aggregate consumption bundle. Epstein–Zin utility implies the following stochastic discount factor M between periods t and $t+1$:

$$M_{t+1} \equiv \beta \frac{a_{t+1}}{a_t} \left(\frac{U(C_{t+1}, l_{t+1})}{U(C_t, l_t)} \right)^{\frac{1-\sigma}{\theta_v}-1} \frac{U_c(C_{t+1}, l_{t+1})}{U_c(C_t, l_t)} \left(\frac{C_{m,t+1}}{C_{m,t}} \frac{C_t}{C_{t+1}} \right)^{b_1-1} \left(\frac{V_{t+1}^{1-\sigma}}{\mathbb{E}_t V_{t+1}^{1-\sigma}} \right)^{1-\frac{1}{\theta_v}}.$$

Producers

The representative intermediate good-producing firm i rents labor $h_{m,t}(i)$ from the representative household to produce the intermediate good $Y_t(i)$. Intermediate goods producers operate in a monopolistically competitive market and face a quadratic cost of changing their nominal price $P_t(i)$. Additionally, they own their capital stock, $K_t(i)$, and incur a quadratic cost $(\phi_k/2) [I_t(i)/K_t(i) - \delta]^2$ when changing the quantity of installed capital.

Each firm issues equity shares $S_t(i)$ and one-period risk-free bonds $B_t(i)$. The firm finances

²²Our main qualitative results are robust to using standard expected utility preferences as in (16). Recursive preferences à la Epstein and Zin allow increasing risk aversion (helping the model generate quantitatively plausible aggregate effects of uncertainty) while keeping the relatively high intertemporal elasticities of substitution needed to ensure sound business cycle properties for the model (see Fernandez-Villaverde and Guerron-Quintana, 2020).

a percentage ν of its capital stock with the one-period bond. The quantity of bonds is then $B_t(i) = \nu K_t(i)$. Total firm cash flows are distributed between payments to bondholders and equity holders. Due to the Modigliani and Miller (1958) theorem, leverage does not impact firm decisions optimally. Instead, leverage allows us to define a concept of equity returns needed to construct a measure of uncertainty consistent with the VIX.

The intermediate goods firms have a constant-returns-to-scale Cobb–Douglas production function, subject to a fixed cost $\Gamma(i)$:

$$Y_t(i) = K_t^\alpha(i) (Z_t h_{m,t}(i))^{1-\alpha} - \Gamma(i),$$

where Z_t denotes productivity. Firm i chooses $h_{m,t}(i)$, $I_t(i)$, and $P_t(i)$ to maximize the expected discounted real cash flows $D_t(i)/P_t(i)$, subject to the production function and the capital accumulation equation:

$$K_{t+1}(i) = \left[1 - \delta - \frac{\phi_k}{2} \left(\frac{I_t(i)}{K_t(i)} - \delta \right)^2 \right] K_t(i) + I_t(i).$$

Each firm takes as given aggregate demand Y_t and the price P_t of the finished goods sector. The market for final goods is perfectly competitive. The representative final goods producer j uses intermediate goods as an input. The aggregate price index is $P_t \equiv \left[P_t^{1-\theta_\mu}(j) dj \right]^{1/(1-\theta_\mu)}$, where θ_μ denotes the elasticity of substitution among intermediate goods.

Monetary Policy and Aggregate Shocks

The monetary authority sets the nominal interest rate R_t to stabilize inflation and output growth:

$$r_t = \bar{r} + \rho_\pi (\pi_t - \bar{\pi}) + \rho_y \Delta y_t,$$

where $r_t \equiv \log R_t$, $\pi_t \equiv \log(P_t/P_{t-1})$, and $\Delta y_t \equiv \log(Y_t/Y_{t-1})$. Variables without time subscript denote steady-state values.

The exogenous shock processes are as follows:

$$a_t = (1 - \rho_a)\bar{a} + \rho_a a_{t-1} + \sigma_{t-1}^a \epsilon_t^a,$$

$$\sigma_t^a = (1 - \rho_{\sigma_a})\bar{\sigma}_a + \rho_{\sigma_a} \sigma_{t-1}^a + \sigma^{\sigma_a} \epsilon_t^{\sigma_a},$$

$$Z_t = (1 - \rho_z)\bar{Z} + \rho_z Z_{t-1} + \sigma_z \epsilon_t^z.$$

The terms ϵ_t^a and ϵ_t^z are first-moment shocks that capture innovations to the households' discount factor and the level of technology. The term $\epsilon_t^{\sigma a}$ is a second-moment shock that captures innovations to the volatility of households' discount factor, capturing uncertainty about the future time path of households' demand. All stochastic shocks are independent, standard normal random variables.

Parametrization and Solution Method

We interpret periods as quarters and parametrize the model to match U.S. macroeconomic data. Following standard practice in the home-production literature, we calibrate the capital share in the production function, α , the weight on market consumption in total consumption, α_1 , and the elasticity of substitution between consumption and leisure, η to match the observed size of the home sector relative to the market (h_m and h_n) and the steady-state capital-output ratio, K/Y . We set the elasticity of substitution between market and nonmarket goods, $1/(1 - b_1)$, equal to 2, a conservative value given the available estimates in the literature—see Gnocchi et al. (2016).

The calibration of the remaining parameters follows Basu and Bundick (2017). The discount factor β is equal to 0.994, the intertemporal elasticity of substitution ψ is 0.95, and risk aversion over the consumption-leisure basket σ is equal to 80. We set the fixed cost of production Γ such that pure profits are zero in the deterministic steady state. The capital depreciation rate δ is 0.025, while the investment adjustment cost is $\phi_k = 2$. The price adjustment cost is $\phi_p = 100$, while the elasticity of substitution of intermediate goods, θ_μ , is equal to 6. The Taylor rule parameters are $\rho_\pi = 1.5$ and $\rho_y = 0.2$; the quarterly gross steady-state inflation rate is $\Pi = 1.005$ (a two-percent annualized inflation target).

Basu and Bundick (2017) calibrate the parameters of first- and second-moment shock processes such that their model produces fluctuations in uncertainty that are consistent with the VIX, an observable indicator of ex-ante stock market volatility. We use the same parametrization and verify the model-VIX dynamics are consistent with the data when studying impulse responses below. To this end, we construct a model-implied VIX index, $\mathbb{V}_t$, as the expected conditional volatility of the return on firm equity:

$$\mathbb{V}_t = 100 * \sqrt{4 * \mathbb{V}\mathbb{A}\mathbb{R}_t R_t^E}, \quad (18)$$

where $\mathbb{V}\mathbb{A}\mathbb{R}_t R_t^E$ is the quarterly conditional variance of the return on equity. We annualize the quarterly conditional variance and then transform the annual volatility units into percentage points. Appendix B summarizes the model calibration.

We approximate the model policy functions by computing a fourth-order Taylor expansion of the equilibrium conditions around the deterministic steady state (e.g., Cacciatore and Ravenna, 2021).

Time Use and the Macroeconomic Effects of Uncertainty

We now discuss how time-use reallocation affects the transmission of uncertainty shocks. Towards this end, we first study the impulse responses to a one-standard-deviation uncertainty shock. Next, we consider a counterfactual economy in which home production ($h_{n,t}$) is held constant at its steady-state level following the same uncertainty shock. In this counterfactual model, households can only reallocate time between market hours and leisure.

Figure 6 (continuous lines) shows that in the model with housework, higher uncertainty results in lower market hours ($h_{m,t}$) and higher home production, with a more modest impact on leisure. For all three variables, the impulse responses are in line with the empirical estimates presented in Figure 3 (Section 2). Furthermore, as housework increases, households reallocate expenditures towards nonmarket consumption, other things being equal. Aggregate investment, output, and inflation decline. Appendix C shows that these model predictions, along with the response of the model-implied VIX in (18), also are consistent with the data—in the Appendix we present local-projection estimates for these variables using the same uncertainty shocks identified in Section 2. The increase in housework—which remains unmeasured in national account data—results in a higher level of households’ welfare-relevant consumption even though consumption expenditures contract by more.

To understand these findings, recall first the insights from the partial-equilibrium analysis. As uncertainty rises, households’ precautionary saving and precautionary labor supply increase. With sticky prices, precautionary savings reduces aggregate demand. Other things being equal, consumption of market goods declines, lowering investment and labor demand. Accordingly, wages and inflation decline. While precautionary saving reduces demand for all goods (including housework and leisure), in equilibrium, households compensate for the shortfall in market expenditure with housework and an increase in the consumption of home goods. Thus, $h_{m,t}$ falls while $h_{n,t}$ increases (together with nonmarket consumption).

We can now answer our main question of interest: Does reallocation between market and nonmarket work (and the corresponding expenditure reallocation from market to nonmarket goods) mitigate or amplify the macroeconomic effects of uncertainty? Figure 6 (dashed lines) shows that

when households cannot adjust hours worked at home, the same uncertainty shock results in a smaller contraction of output and hours worked but a larger drop in total consumption. Moreover, the decline in wages (and thus inflation) is larger. Quantitatively, time-use reallocation increases the output contraction by roughly one-third relative to the counterfactual scenario.

The intuition from the partial-equilibrium analysis also rationalizes these findings. When uncertainty reduces labor demand and real income, intratemporal substitution of market expenditures with home goods—a margin that would not be feasible without home production—results in a larger contraction of aggregate demand and hours worked. Thus, in general equilibrium, empirically plausible complementarity between market-hours work and consumption expenditures on market goods more than offsets the positive effects of intertemporal substitution—i.e., that households’ ability to reallocate time and expenditures in future adverse states of the world weakens precautionary saving, all else being equal. Ultimately, the higher aggregate demand elasticity to uncertainty accounts for about one-third of the decline in aggregate output.

5 Macroeconomic Policy and Substitution Towards Housework

Thus far, the analysis has focused on how uncertainty affects households’ incentives to allocate time use due to precautionary motives. The COVID-19 pandemic has brought the role of policies that lead households to reallocate time to the forefront of policy and academic discussions. The closure of contact-intensive industries and the lockdowns that encompassed stay-at-home orders, curfews, and similar societal restrictions forced households to cut expenditures on market-produced goods and employment-related activities (e.g., accommodation and food services, commuting) while increasing housework (e.g., meal preparation, cleaning, household repairs, childcare, etc.).

In this final section, we discuss how policies that affect time allocation (a first-moment shock) can interact with the effects of uncertainty. We model these policies assuming that government interventions change the weight of market consumption in the total consumption aggregator—the parameter α_1 in equation (10). This reduced-form approach keeps the analysis simple by proxying a policy intervention with a change in preferences. In this regard, the approach parallels, for instance, the literature that studies the macroeconomic effects of trade openness—which focuses on changes in the degree of consumers’ home bias.

Figure 7 plots impulse responses following an exogenous 1% increase in the consumption share of nonmarket goods (holding uncertainty constant). As households reallocate expenditure shares,

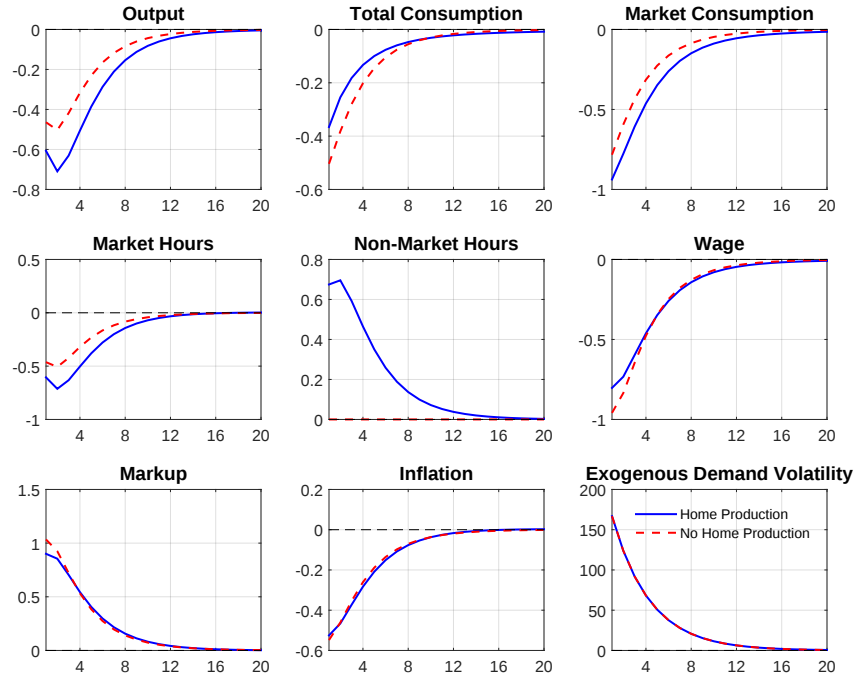


Figure 6: Impulse responses following a one-standard-deviation uncertainty shocks. The continuous line represents the baseline model of housework; the dashed line represents a counterfactual economy where home production is constant. Variables are in percentage deviations from the steady state, except for inflation, which is annualized.

housework increases. In contrast, market hours, aggregate demand, and output fall. Wages increase to clear the labor market, and the real marginal cost and inflation increase. Qualitatively, the dynamics of market hours and output are identical to the effects of endogenous time reallocation induced by an uncertainty increase—measured by the difference between the continuous and dashed lines in Figure 6.²³ Thus, policies that induce households to substitute market hours with housework compound the adverse effects on aggregate demand and output brought about by time-use variation at times of heightened uncertainty.

We next conduct a final experiment to study the implications of an increase in uncertainty accompanied by a policy that induces households to reallocate time and expenditures. We calibrate the size of the uncertainty shock, σ^{σ_a} , to match the VIX increase observed in March 2020. Concerning the change in the expenditure share on market goods, α_1 , we target the total change in home production observed during the pandemic. Since ATUS data collection was suspended altogether during the COVID-19 shutdown (resuming only in mid-May), time diary-based information does not exist between March and May 2020. Thus, we can use only an estimate of time allocation patterns during the pandemic recession. We rely on the cyclical substitution rate estimated in Section 2 to infer the change in housework from the variation in hours of market work. The approach is similar to Leukhina and Yu (2022), who infer the change in home production from the change in average weekly market hours between the months of February and April of 2020.²⁴ Concerning the persistence of the shocks, notice first that much of the spike in the VIX faded away by August 2020. Moreover, hours worked on the market returned to their pre-COVID level about a year later. We set the persistence of shocks to match these figures.

Figure 8 (continuous lines) plots the impulse responses following the simultaneous increase in volatility and the reduction in the market-goods expenditure. The dashed line plots dynamics for a counterfactual model in which no substitution towards housework is possible: home production is kept constant at its steady-state level, and the government policy is absent. Thus, in the counterfactual scenario, the impulse responses measure the effects of higher uncertainty in the absence of any reallocation between market and nonmarket work.

Figure 8 shows that higher uncertainty in isolation acts as a negative demand shock for a given time allocation. However, the substitution from market to nonmarket hours resulting from higher

²³Wages and inflation respond more strongly since a change in α_1 directly affects labor supply. In contrast, the uncertainty-induced reallocation toward housework is an endogenous response along the labor supply curve.

²⁴This approach likely underestimates the actual change in home production since our estimates of the foregone market production allocated to home production (the β' s) obtain for a sample period in which time-use reallocation shocks are relatively unimportant (see AHK 2013).

future expected volatility and government policy can temporarily produce dynamics consistent with a supply-side shock. In particular, Figure 8 (dashed lines) suggests that time-use reallocation could reduce output by an additional 2 percent and increase annualized inflation by approximately 0.8 percent. Government policies can thus exacerbate the contraction of aggregate demand due to uncertainty to a greater extent, but they may also moderate its deflationary impact to the point of even becoming inflationary, depending on their stringency and duration. A caveat to these results is that we do not account for the beneficial effects on output and welfare of limiting contagion, and the wide range of extraordinary monetary and fiscal policies that were implemented at the time.

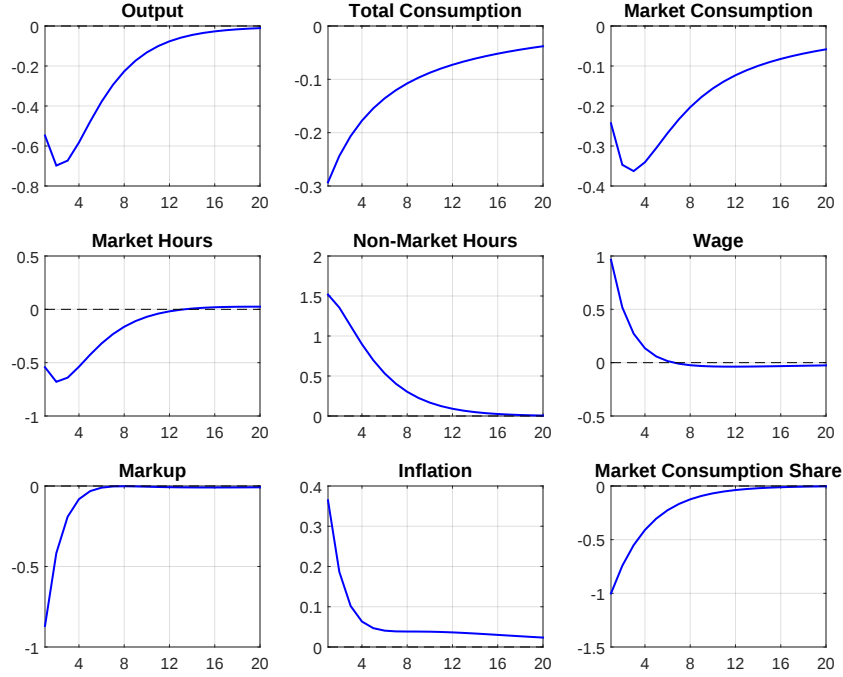


Figure 7: Impulse responses following a one-percent decline in the market-consumption expenditure share. Variables are in percentage deviations from the steady state, except for inflation, which is annualized.

6 Conclusions

We estimated the effects of uncertainty on time use and discuss its macroeconomic implications. Using data from the ATUS, we have first constructed cyclical measures of aggregate housework and leisure. Using these novel time series, we estimated local projections to identify the response of market hours, housework, and leisure following an increase in uncertainty shock. We find that higher uncertainty increases housework and reduces market work hours, with modest effects on leisure.

In the second part of the paper, we built a model of housework with time-varying uncertainty that replicates the empirical results. The model demonstrates that substitution between market and nonmarket work provides an additional insurance margin to households, weakening precautionary savings and labor supply. However, time-use reallocation also lowers aggregate demand, ultimately amplifying the contractionary effects of uncertainty. Our contribution also suggests that uncertainty

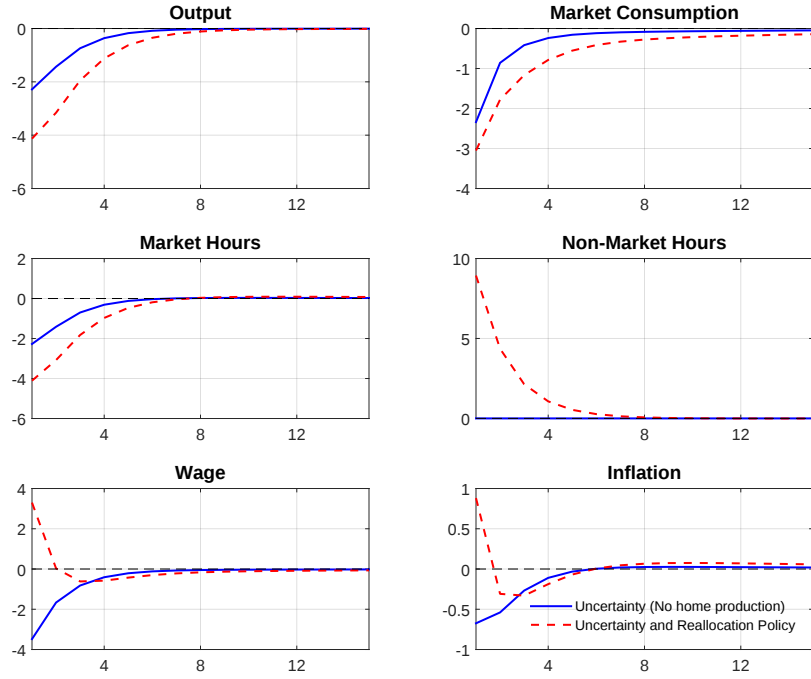


Figure 8: Impulse responses following a joint increase in uncertainty and the market-consumption expenditure share. The continuous line represents the baseline model of housework; the dashed line represents a counterfactual economy where home production is constant. Variables are in percentage deviations from the steady state, except for inflation, which is annualized.

generates significant changes in economic activity – such as home production – that are not captured by consumption expenditures. While not measured by national accounts, this variation is welfare relevant and it is central to households’ labor supply and savings decisions at times of heightened uncertainty.

Finally, we have shown that policies that reallocate time use towards housework (e.g., lock-down policies) amplify the recessionary effects of uncertainty and can result in aggregate dynamics consistent with a supply-side shock.

Our work suggests promising venues for future research. First, our approach to infer cyclical variations in time use can easily be applied to study the transmission of other macroeconomic shocks on time use. Second, even within the realm of uncertainty shock transmission, a few questions remain unaddressed. For example, we focused on aggregate outcomes without exploring potential heterogeneity in time use across households and its macroeconomic implications. Moreover, further analysis is warranted to understand the role of monetary and fiscal policy in households that reallocate time in response to uncertainty, beyond policies that directly affect time use.

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Online Appendix to: “Time Use and Macroeconomic Uncertainty”

Authors: M. Cacciatore, S. Gnocchi, and D. Hauser

A Time Series Analysis of Time Use

Variation of changes in market work hours across states

This section shows that the variation of biannual changes in market work hours across states, documented in Aguiar et al. (2013) for 2003–2010, extends 1. to our full sample 2003–2019 (see Table 1), and 2. to the alternative definitions of the dependent variable (i.e., changes in market hours at annual and quarterly frequency, see Table 2). Increasing the frequency from biannual, to annual and quarterly changes increases the degree of variation in the changes of market hours across states, as further shown in Figure A.1.

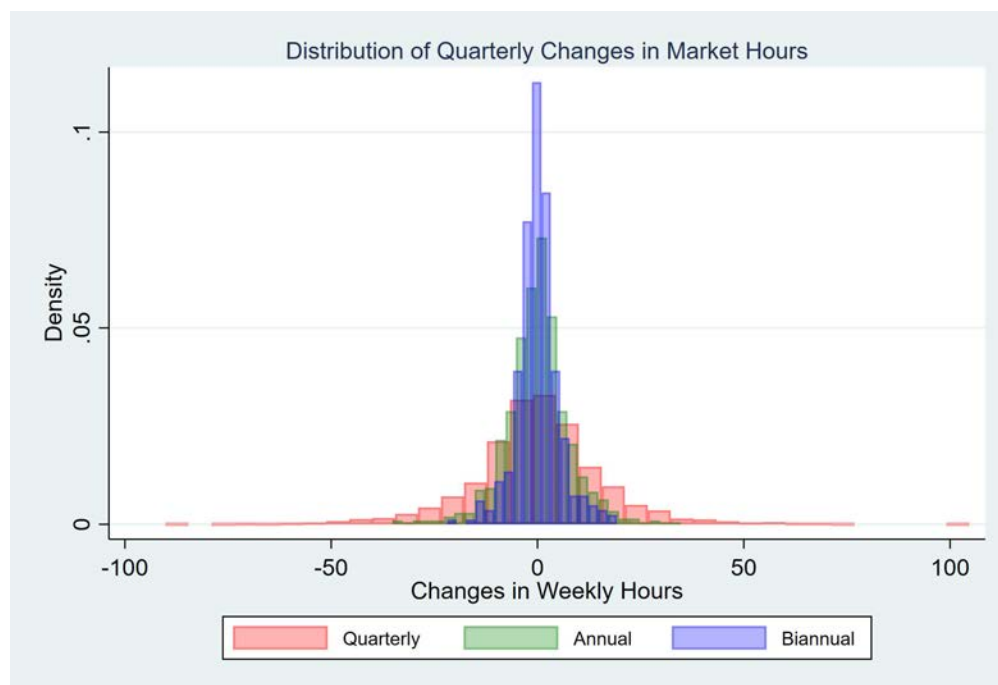


Figure A.1: Density histogram of state-level changes in market hours worked ($\Delta\tau_{st}^{market}$) for different frequencies.

	Pooled Sample (1)	2006/05 vs 2004/03 (2)	2008/07 vs 2006/05 (3)	2010/09 vs 2008/07 (4)	2012/11 vs 2010/09 (5)	2014/13 vs 2012/11 (6)	2016/15 vs 2014/13 (7)	2019/17 vs 2016/15 (8)
Mean	0.03	0.57	0.61	-2.15	0.23	-0.09	0.49	0.54
Standard Deviation	3.32	2.93	3.43	3.33	3.43	3.14	3.47	2.73
10th Percentile	-3.68	-2.99	-3.00	-6.31	-3.41	-3.06	-2.71	-2.66
25th Percentile	-2.14	-0.71	-1.42	-3.68	-1.68	-2.03	-1.71	-1.56
50th Percentile	0.19	0.89	0.43	-2.66	0.31	-0.11	0.72	1.36
75th Percentile	1.92	2.48	1.24	0.19	2.83	1.47	2.48	1.92
90th Percentile	3.95	2.51	6.61	2.47	3.59	4.10	4.44	3.20
Percent Negative Changes	50.14	39.22	49.02	74.51	49.02	50.98	41.18	47.06

Table 1: Summary statistics of changes in market work hours per week and state ($\Delta \tau_{st}^{market}$), defined as differences between the non-overlapping two-year periods. Observations are weighted with each state's population.

	Biannual	Annual	Quarterly
Mean	0.03	0.02	0.002
Standard Deviation	3.32	5.02	10.28
10th Percentile	-3.68	-5.95	-11.38
25th Percentile	-2.14	-2.66	-5.42
50th Percentile	0.19	0.14	0.03
75th Percentile	1.92	2.67	5.22
90th Percentile	3.95	5.75	11.11
Percent Negative Changes	50.14	49.39	49.87

Table 2: Summary statistics for different definitions of changes in market work hours per week and state ($\Delta\tau_{st}^{market}$). Observations are weighted with each state’s population.

Alternative Definitions of the Dependent Variable

AHK estimate their benchmark regression

$$\Delta\tau_{st}^j = \alpha^j - \beta^j \Delta\tau_{st}^{market} + \varepsilon_{st}^j,$$

with $\Delta\tau_{st}^j = \tau_{s,t}^j - \tau_{s,t-1}^j$ defined as the difference in average time spent on activity j in state s from one non-overlapping two-year period to another. In this section, we analyze robustness with respect to alternative specifications of $\Delta\tau_{st}^j$, specifically:

- **Annual** state-level data, where $\Delta\tau_{st}^j$ is defined as the year-over-year change in time use of activity j , in state s , for a given year.
- **Quarterly** state-level data, where $\Delta\tau_{st}^j$ captures the year-over-year change in time use of activity j , in state s , for a given quarter.
- **Rolling-window yearly average at quarterly frequency** at the state level, where $\Delta\tilde{\tau}_{st}^j$ captures the year-over-year change in the average time use for activity j in state s , over the last four quarters, i.e. $\tilde{\tau}_{st}^j = \text{mean}(\tau_{s,t-3}^j, \tau_{s,t-2}^j, \tau_{s,t-1}^j, \tau_{s,t}^j)$.

Table 3 reports estimates based on weighted least squares, where states are weighted by their

Time Use Category	$\hat{\beta}^j$ biannual 2003–10 (1)	$\hat{\beta}^j$ biannual 2003–2019 (2)	$\hat{\beta}^j$ annual 2003–2019 (3)	$\hat{\beta}^j$ quarterly 2003–2019 (4)	$\hat{\beta}^j$ quarterly rolling window (5)
Nonmarket Work	0.28	0.25	0.25	0.25	0.24
Leisure	0.52	0.60	0.61	0.61	0.61

Table 3: Column 1 reports original estimates in AHK, using ATUS data from 2003–2010. Column 2 reports estimates for the dependent variable defined as biannual state-level differences, using ATUS data from 2003–2019. Column 3 reports estimates based on year-over-year changes, column 4 estimates based on year-over-year quarterly changes, and column 5 estimates on quarterly year-over-year rolling-window averages.

Time Use Category	$\hat{\beta}^j$ <i>demo</i> (1)	$\hat{\beta}^j$ <i>no demo</i> (2)	$\hat{\beta}^j$ <i>demo and time</i> (3)
Nonmarket Work	0.25	0.24	0.24
Leisure	0.61	0.60	0.61

Table 4: Column 1 reports estimates based on quarterly year-over-year changes, when controlling for state-level demographics (*demo*). Column 2 reports estimated coefficients based on quarterly year-over-year changes without controlling for state-level demographic changes (*no demo*). And column 3 reports estimates based on quarterly year-over-year changes with controls for state-level demographic changes and time-fixed effects (*demo and time*).

population, and where changes in demographic variables at the state level are controlled for. Table 4 uses quarterly state-level data to further show that controlling for state-level demographic changes and/or for time-fixed effects does not significantly affect the estimated coefficients.

Robustness: Are the Estimated Coefficients Time-Dependent?

p-value $H_0 : \beta_t^j = \beta^j$	Nonmarket Work	Leisure
1995	.59	.44
1998	.07	.22
2004	.62	.92
2005	.83	.72
2006	.36	.58
2007	.85	.66
2008	.95	.36
2009	.29	.03
2010	.63	.06
2011	.72	.53
2012	.32	.13
2013	.38	.77
2014	.59	.90
2015	.06	.03
2016	.48	.27
2017	.86	.19
2018	.90	.29
2019	.82	.33

Table 5: P-values for the null hypothesis $H_0 : \beta_t^j = \beta^j$, with β_t^j from (3), when the dependent variable is defined as year-over-year change in time use, and β^j from (2) estimated over the entire sample 2003–2019.

Robustness: Are Home-Production Shocks Important Drivers for Nonmarket Hours?

To rule out the importance of aggregate drivers in explaining cyclical fluctuations of nonmarket hours and leisure we follow AHK (see Section V, p.1689 and following), and estimate the following regression at the individual level:

$$\tau_{ist}^j = \alpha_m - \beta_m^h \tau_{ist}^{market} + \gamma^h \mathbf{A}_{st} + \mathbf{D}_t + \mathbf{S}_s + \delta_m^h \mathbf{X}_{its} + \varepsilon_{ist}^h$$

where τ_{ist}^j denotes hours dedicated to activity j , by individual i in state s in time t , τ_{ist}^{market} denotes market work hours of the individual, $\mathbf{D}_t$ and $\mathbf{S}_s$ are year and state dummies, $\mathbf{X}_{its}$ denotes a vector of demographic and educational controls (the same ones used in the cross-state regressions), and $\mathbf{A}_{st}$ denotes some measure of aggregate labor market conditions at the state level. We consider average work hours in state s in time t from ATUS data ($\mathbf{A}_{st} = \tau_{st}^{market}$), state-level unemployment rate from the BLS ($\mathbf{A}_{st} = u_{st}$), state-level employment to population ratio from the BLS ($\mathbf{A}_{st} = e_{st}$), and state-level labor force participation rate from the BLS ($\mathbf{A}_{st} = p_{st}$). The interpretation of the

estimated coefficient γ^h is as follows:

- For $\mathbf{A}_{st} = \tau_{st}^{market}$, $\gamma^h < 0$ implies that individuals spend more time on nonmarket work when aggregate market work hours decrease, holding constant their individual market work hours. This would suggest that individuals experience positive shocks to their nonmarket work time in periods of decreasing aggregate market work. The same logic applies to $\mathbf{A}_{st} = e_{st}$ and $\mathbf{A}_{st} = p_{st}$.
- For the regression using $\mathbf{A}_{st} = u_{st}$, $\gamma^h > 0$ implies that individuals spend more time on nonmarket work when aggregate unemployment is high, holding constant their market work hours. This would suggest that individuals experience positive shocks to their nonmarket work in periods of increasing aggregate unemployment.

In all cases, a statistically significant coefficient γ^h would imply the existence of positive (negative) home production shocks during recessions (expansions). We confirm the main takeaways in AHK using available data from 2003–2019. Specifically, for all specifications we cannot reject the null hypothesis that $\gamma^h = 0$ (at 95%). Hence, individuals adjust their nonmarket and leisure time when their market hours change, but they do not appear to adjust their nonmarket and leisure hours systematically with aggregate labor market conditions (holding their market hours constant). Hence, these regressions show that the aggregate state of the economy (measured either by aggregate market hours or unemployment at the state level) is insignificant in explaining individual home hours once individual market hours are controlled for.

Local Projections with an Alternative Identification

In this Appendix, we show that our results are robust to including the contemporaneous values of macroeconomic variables as controls in equation (5):

$$vix_t = \alpha + \sum_{i=1}^p \phi_i^{vix} vix_{t-i} + \sum_{i=0}^p \phi_i^{ip} \Delta Y_{t-i} + \sum_{i=0}^p \phi_i^n \Delta H_{t-i} + \sum_{i=0}^p \phi_i^{oil} oil_{t-i} + \sum_{i=0}^p \phi_i^{ffr} ffr_{t-i} + \mu_t^{vix}, \quad (\text{A-19})$$

where vix_t denotes the VIX, ΔY_t is the log-difference in real GDP, ΔH_t is the log-difference in hours worked, oil_t is the level of crude oil prices, and ffr_t is the federal funds rate. This alternative specification embeds a different identifying assumption: innovations to the VIX do not affect contemporaneously real economic activity, as in Bloom (2009). The respective dynamics for market hours, nonmarket hours and leisure time are shown in Figure A.2.

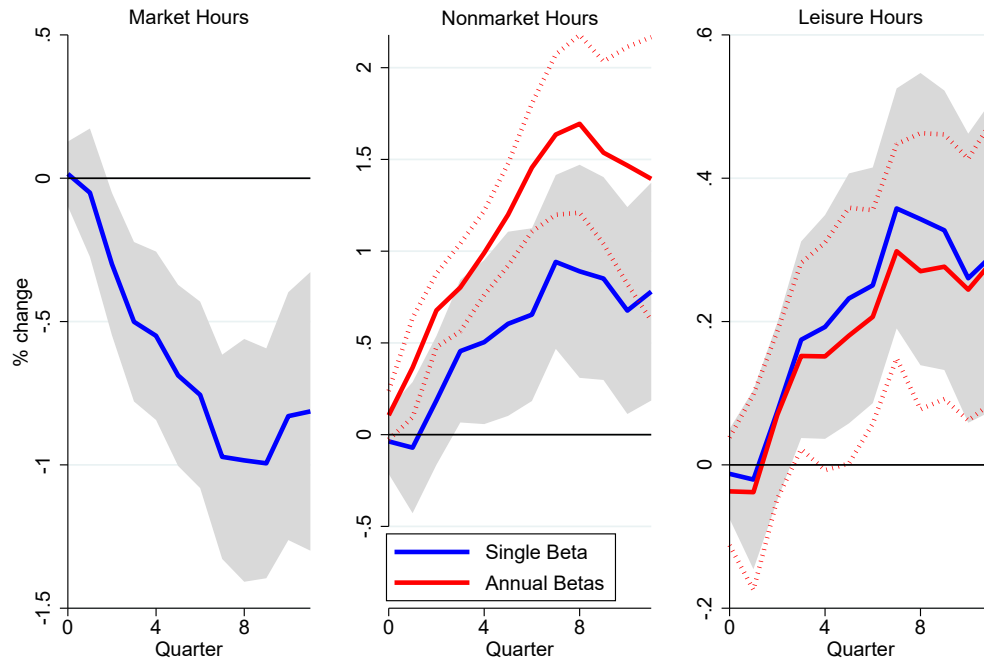


Figure A.2: Estimated impulse responses and 90% confidence intervals for hours worked (from CPS), nonmarket hours and leisure time, conditional on a one-standard-deviation uncertainty shock, using data from 1990:Q1–2019:Q4. Nonmarket hours and leisure time series are constructed with β^j from (2) estimated over the entire ATUS data from 2003–2019 (blue line, labeled as ‘average beta’), and alternatively with β_t^j from (3) estimated year by year (red line, labeled as ‘annual betas’).

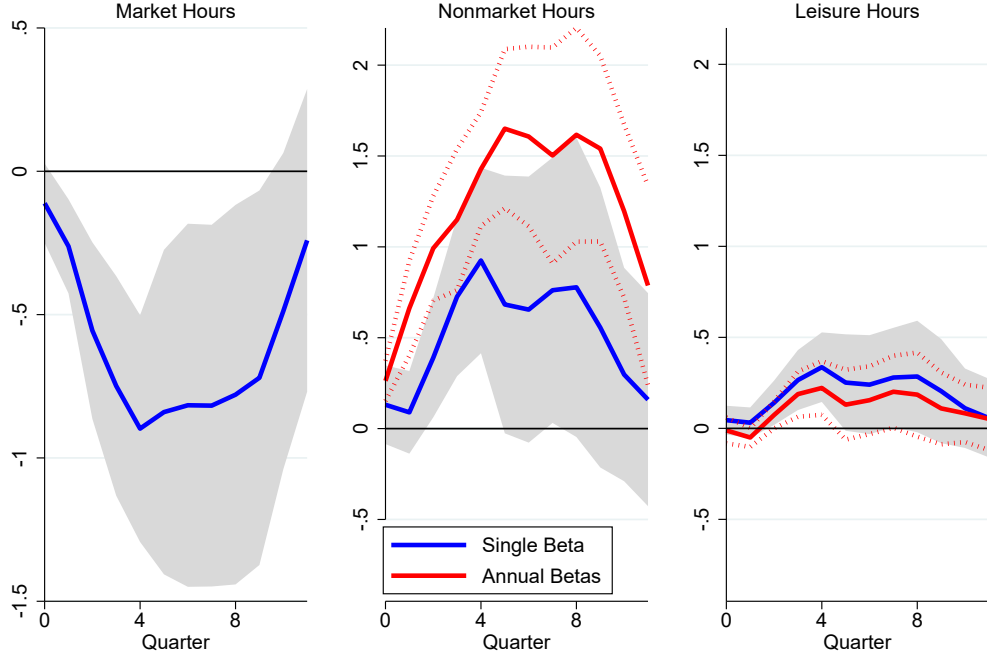


Figure A.3: Estimated impulse responses and 90% confidence intervals for hours worked (from BLS), nonmarket hours and leisure time, conditional on a one-standard-deviation **financial uncertainty** shock, using data from 1990:Q1–2019:Q4. Nonmarket hours and leisure time series are constructed with β^j from (2) estimated over the entire ATUS data from 2003–2019 (blue line, labeled as ‘average beta’), and alternatively with β_t^j from (3) estimated year by year (red line, labeled as ‘annual betas’).

Local Projections with Alternative Uncertainty Measures

This section shows that our results are robust to considering alternative measures of uncertainty. Specifically, instead of including the VIX to identify uncertainty shocks (regression (5) in the main text), we use the indices for macro and financial uncertainty constructed by Jurado et al. (2015). Figure A.3 plots time use dynamics conditional on financial uncertainty shocks at monthly and quarterly frequency. Figure A.4 show the same dynamics for macro uncertainty shocks.

B Model Equations

Here we present the full set of the model equilibrium conditions.

- Welfare function:

$$V_t = \left\{ a_t [U(C_t, l_t)]^{\frac{1-\sigma}{\theta_v}} + \beta (\mathbb{E}_t V_{t+1}^{1-\sigma})^{\frac{1}{\theta_v}} \right\}^{\frac{\theta_v}{1-\sigma}} \quad (\text{A-20})$$

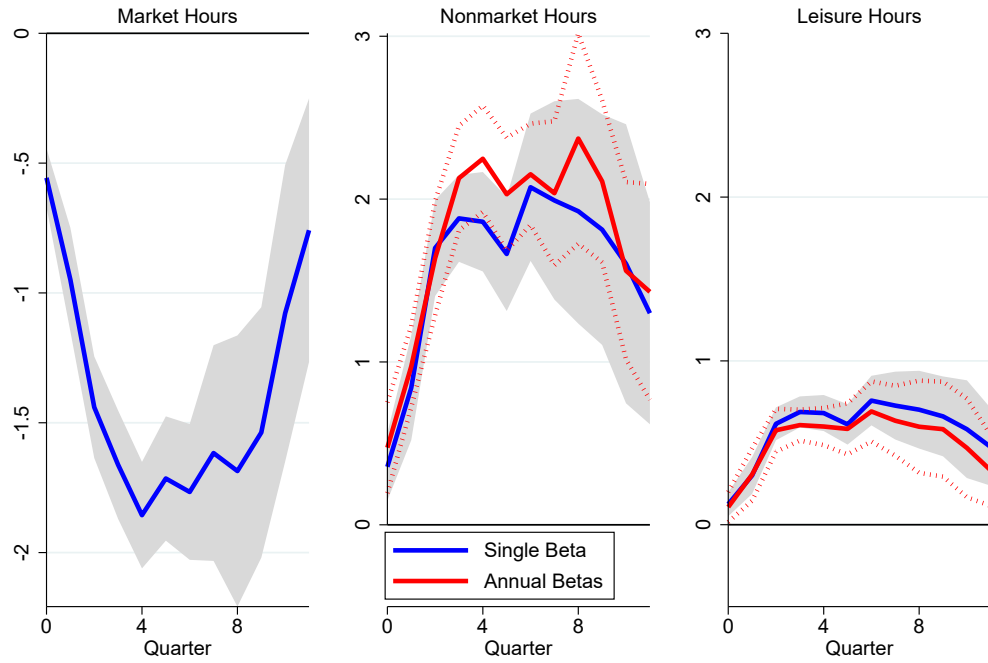


Figure A.4: Estimated impulse responses and 90% confidence intervals for hours worked (from BLS), nonmarket hours and leisure time, conditional on a one-standard-deviation **macro uncertainty** shock, using data from 1990:Q1–2019:Q4. Nonmarket hours and leisure time series are constructed with β^j from (2) estimated over the entire ATUS data from 2003–2019 (blue line, labeled as ‘average beta’), and alternatively with β_t^j from (3) estimated year by year (red line, labeled as ‘annual betas’).

- Stochastic discount factor:

$$M_{t+1} \equiv \beta \frac{a_{t+1}}{a_t} \left(\frac{U(C_{t+1}, l_{t+1})}{U(C_t, l_t)} \right)^{\frac{1-\sigma}{\theta_v} - 1} \frac{U_c(C_{t+1}, l_{t+1})}{U_c(C_t, l_t)} \left(\frac{C_{m,t+1}}{C_{m,t}} \frac{C_t}{C_{t+1}} \right)^{b_1 - 1} \left(\frac{V_{t+1}^{1-\sigma}}{\mathbb{E}_t V_{t+1}^{1-\sigma}} \right)^{1 - \frac{1}{\theta_v}}$$

- Budget constraint:

$$I_{n,t} + C_{m,t} + \frac{P_t^E}{P_t} S_{t+1} + \frac{1}{R_t^R} \nu K_{m,t+1} = \frac{W_t}{P_t} h_{m,t} + \left(\frac{D_t^E}{P_t} + \frac{P_t^E}{P_t} \right) S_t + \nu K_{m,t}$$

- Intratemporal optimality condition (market consumption vs. market hours worked):

$$\frac{W_t}{P_t} = \frac{U_l(C_t, l_t)}{U_c(C_t, l_t)} \frac{1}{\alpha_1} \left(\frac{C_{m,t}}{C_t} \right)^{1-b_1}$$

- Intratemporal optimality condition (home consumption vs. nonmarket hours worked):

$$(1 - \alpha_1) \left(\frac{C_{n,t}}{C_t} \right)^{b_1 - 1} = \frac{U_l(C_t, l_t)}{U_c(C_t, l_t)}$$

- First-order condition with respect to equity shares (S_{t+1}):

$$\frac{P_t^E}{P_t} = \mathbb{E}_t \left\{ M_{t+1} \left(\frac{D_{t+1}^E}{P_{t+1}} + \frac{P_{t+1}^E}{P_{t+1}} \right) \right\}$$

- First-order condition with respect to one-period riskless bond (B_{t+1}):

$$1 = R_t^R \mathbb{E}_t \{ M_{t+1} \}$$

- Production function:

$$Y_t = Z_t^{norm} [K_{m,t} U_{m,t}]^\alpha [Z_{m,t} h_{m,t}]^{1-\alpha} - \Psi$$

where Z_t^{norm} is an aggregate TFP, used to normalization steady-state output to one.

- Law of motion for market capital:

$$K_{m,t+1} = \left(1 - \delta(U_{m,t}) - \frac{\phi_{k_m}}{2} \left(\frac{I_{m,t}}{K_{m,t}} - \delta \right)^2 \right) K_{m,t} + I_{m,t}$$

- Market-capital utilization:

$$\delta(U_{m,t}) = \delta + \delta_1 (U_{m,t} - U_m) + \frac{\delta_2}{2} (U_{m,t} - U_m)^2$$

where U_m denotes steady-state capital utilization on the market.

- Cash flows:

$$\frac{D_t}{P_t} = Y_t - \frac{W_t}{P_t} h_{m,t} - I_{m,t} - \frac{\phi_p}{2} \left(\frac{\Pi_t}{\bar{\Pi}} - 1 \right)^2 Y_t$$

- Firms' optimality condition with respect to market hours:

$$\frac{W_t}{P_t} h_{m,t} = (1 - \alpha) RMC_t Z_t^{norm} [K_{m,t} U_{m,t}]^\alpha [Z_{m,t} h_{m,t}]^{1-\alpha}$$

where RMC_t denotes real marginal costs (denoted by χ in the code).

- Firms' optimality condition with respect to market capital:

$$\frac{R_t^K}{P_t} U_{m,t} K_{m,t} = \alpha RMC_t Z_t^{norm} [K_{m,t} U_{m,t}]^\alpha [Z_{m,t} h_{m,t}]^{1-\alpha}$$

- First-order condition with respect to utilization of market capital:

$$q_t^M (\delta_1 + \delta_2 (U_{m,t} - U_m)) U_{m,t} K_{m,t} = \alpha RMC_t Z_t^{norm} [K_{m,t} U_{m,t}]^\alpha [Z_{m,t} h_{m,t}]^{1-\alpha}$$

- Optimal pricing:

$$\phi_p \left(\frac{\Pi_t}{\bar{\Pi}} - 1 \right) \left(\frac{\Pi_t}{\bar{\Pi}} \right) = (1 - \theta_\mu) + \theta_\mu RMC_t + \phi_p \mathbb{E}_t \left\{ M_{t+1} \frac{Y_{t+1}}{Y_t} \left(\frac{\Pi_{t+1}}{\bar{\Pi}} - 1 \right) \left(\frac{\Pi_{t+1}}{\bar{\Pi}} \right) \right\}$$

- Euler equation for market capital:

$$q_t^M = \mathbb{E}_t \left\{ M_{t+1} \left[U_{m,t+1} \frac{R_{t+1}^K}{P_{t+1}} + q_{t+1}^M \left(1 - \delta(U_{m,t+1}) - \frac{\phi_{k_m}}{2} \left(\frac{I_{m,t+1}}{K_{m,t+1}} - \delta \right)^2 + \phi_{k_m} \left(\frac{I_{m,t+1}}{K_{m,t+1}} - \delta \right) \left(\frac{I_{m,t+1}}{K_{m,t+1}} \right) \right) \right] \right\}$$

- Optimality condition for market investment:

$$\frac{1}{q_t^M} = 1 - \phi_{k_m} \left(\frac{I_{m,t}}{K_{m,t}} - \delta \right)$$

- Dividends:

$$\frac{D_t^E}{P_t} = \frac{D_t}{P_t} - \nu \left(K_{m,t} - \frac{1}{R_t^R} K_{m,t+1} \right)$$

- Taylor rule:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) [\bar{r} + \rho_\pi (\pi_t - \bar{\pi}) + \rho_y \Delta y_t]$$

with $x_t = \log X_t$ for a generic variable X_t , and where $\Delta y_t = y_t - y_{t-1}$.

- Euler equation for a zero-net supply nominal bond:

$$1 = R_t \mathbb{E}_t \left\{ \frac{M_{t+1}}{\Pi_{t+1}} \right\}$$

$$1 = \beta \mathbb{E}_t \left\{ \frac{a_{t+1}}{a_t} \left(\frac{U(C_{t+1}, l_{t+1})}{U(C_t, l_t)} \right)^{\frac{1-\sigma}{\theta_v}-1} \frac{U_c(C_{t+1}, l_{t+1})}{U_c(C_t, l_t)} \left(\frac{C_{m,t+1}}{C_{m,t}} \frac{C_t}{C_{t+1}} \right)^{b_1-1} \left(\frac{V_{t+1}^{1-\sigma}}{\mathbb{E}_t V_{t+1}^{1-\sigma}} \right)^{1-\frac{1}{\theta_v}} \frac{R_t}{\Pi_{t+1}} \right\}$$

- Definition of markups:

$$\mu_t = (RMC_t)^{-1}$$

- Rotemberg cost definition:

$$\Phi_t = 1 + \frac{\phi_p}{2} \left(\frac{\Pi_t}{\bar{\Pi}} - 1 \right)^2 Y_t$$

- Preference shock:

$$a_t = (1 - \rho_a) \bar{a} + \rho_a a_{t-1} + \sigma_{t-1}^a \epsilon_t^a$$

- Preference volatility shock:

$$\sigma_t^a = (1 - \rho_{\sigma_a}) \bar{\sigma}_a + \rho_{\sigma_a} \sigma_{t-1}^a + \sigma^{\sigma_a} \epsilon_t^{\sigma_a}$$

- Labor-productivity shock:

$$Z_{m,t} = (1 - \rho_{z_m}) \bar{Z}_m + \rho_{z_m} Z_{m,t-1} - \bar{\sigma}_z \epsilon_t^z$$

where $\bar{Z}_m = 1$

- Aggregate TFP:

$$z_t^{norm} = \rho_{z^{norm}} z_{t-1}^{norm} + (1 - \rho_{z^{norm}}) z^{n\bar{o}rm} + \sigma_{t-1}^z \epsilon_t^z$$

- TFP volatility shocks:

$$\sigma_t^z = (1 - \rho_{\sigma_z})\bar{\sigma}_z + \rho_{\sigma_z}\sigma_{t-1}^z + \sigma^{\sigma_z}\epsilon_t^{\sigma_z}$$

Parameterization

Table 4 below summarizes the parameterization of the model.

TABLE 4: MODEL PARAMETERS

<i>Calibrated Parameters</i>	
Discount factor	$\beta = 0.994$
Intertemporal elasticity of substitution	$\psi = 0.95$
Risk aversion	$\gamma = 2$
Elasticity of substitution between market and home consumption	$1/b = 2$
Expenditure share on market on goods	$a_1 = 0.4568$
Elasticity of substitution between total consumption and leisure	$\eta = 0.5258$
Capital share production function	$\alpha = 0.1598$
Capital depreciation rate	$\delta = 0.025$
Fixed production cost	$\Gamma = 0.2$
Investment adjustment cost	$\phi_k = 2$
Elasticity of substitution of intermediate goods	$\theta_\mu = 6$
Price adjustment cost	$\phi_p = 100$
Monetary policy inflation coefficient	$\rho_\pi = 1.5$
Monetary policy output coefficient	$\rho_y = 0.2$
Demand level shock, std. deviation	$\sigma^a = 0.00262$
Demand level shock, persistence	$\rho_a = 0.93564$
Demand volatility shock, std. deviation	$\sigma^{\sigma_a} = 0.0025$
Demand volatility shock, persistence	$\rho_{\sigma_a} = 0.74227$
TFP shock, std. deviation	$\sigma_z = 0.0012857$
TFP shock, persistence	$\rho_z = 0.98793$

C Local Projections for Macroeconomic Variables

Figure A.5 shows the estimated dynamics for a set of macro variables to a one-standard deviation uncertainty shock.

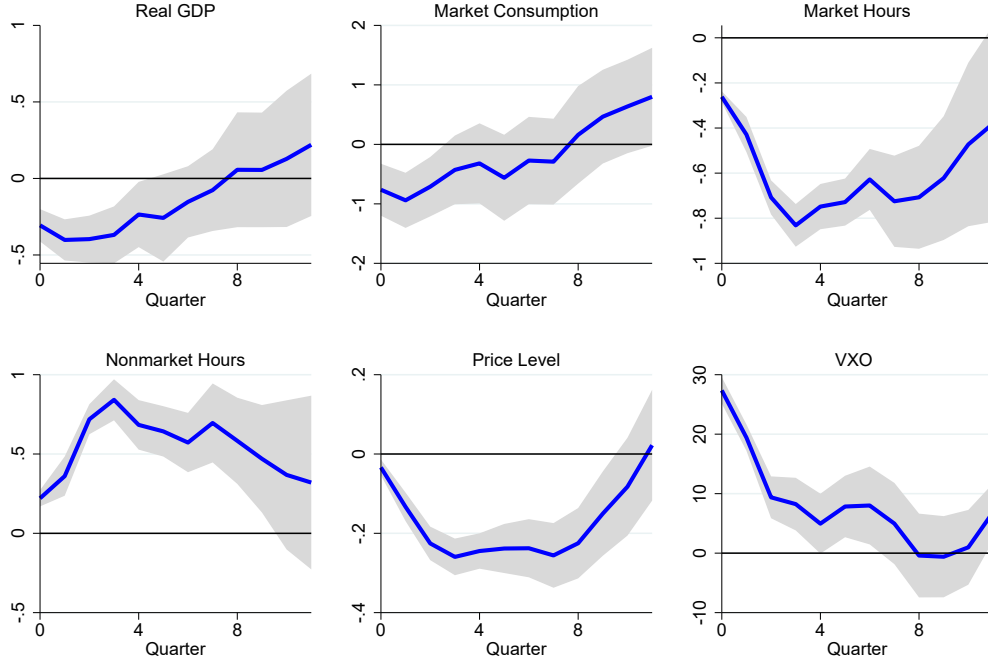


Figure A.5: Estimated impulse responses and 90% confidence intervals for real GDP, market consumption, market hours, nonmarket hours, price level and the VIX, conditional on a one-standard-deviation uncertainty shock, using data from 1990:Q1–2019:Q4.

Specifically, real GDP per capita is defined as Real Gross Domestic Product (GDPC1) taken from FRED (Federal Reserve Economic Data, St. Louis FED), divided by Civilian Non-institutional Population (16 Years and Over) taken from the BLS. Market consumption per capita is defined as the sum of nondurable goods consumption (PCEND) and services consumption (PCES) taken from FRED, divided by Civilian Non-institutional Population (16 Years and Over) taken from the BLS. Finally, the price level is defined as the GDP deflator associated with our Real GDP series (GDPDEF), again taken from FRED.