Work from Home, Business Entry and Exit, and the Macroeconomy

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Abstract

Work from home became more than five times as prevalent following the COVID-19 pandemic. We study the macroeconomic impacts of this shift. Using a quantitative model with business dynamism and optimal remote work choices by heterogeneous firms, we show – analytically and empirically – how remote work affects firm entry and exit through changes in profitability. The parameterized model suggests that 1/4 of the observed post-pandemic surge in firm entry can be accounted for by more prevalent remote work arrangements. This also shifts the firm size distribution towards smaller businesses, improves allocative efficiency, raises output, consumption and welfare.

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1 Introduction

The COVID-19 pandemic gave rise to an unprecedented adoption of remote work arrangements. According to U.S. survey data, about one quarter of workdays occur remotely since the pandemic ended – more than five times that of the pre-pandemic average (see Barrero et al., 2023). While recent studies emphasize the implications of the large shift towards remote work for individual firms and workers, to sectors or city structures (see e.g. Barrero et al., 2023; Decker and Haltiwanger, 2023; Hansen et al., 2023), in this paper we study its *macroeconomic impact*.

Remote work arrangements entail both a cost and benefit to individual firms.[1] Therefore, it is a priori unclear how changes in the prevalence of work from home may impact the rest of the macroeconomy. We show – both empirically and theoretically – that the link between the two rests on changes in the incentives to start new businesses. Indeed, the "surprising surge in applications for new businesses" (see Decker and Haltiwanger, 2023, p.1) in the U.S. following the COVID-19 pandemic will lie at the heart of our analysis.

We proceed in three steps. First, we develop a stylized model to analytical show that changes in work from home arrangements impact business entry and exit. Second, we link multiple micro-datasets and show that our model predictions hold empirically. Finally, we generalize our stylized model along several dimensions and *quantify* the extent to which increased work from home rates can account for the surge in business entry and what implications this has for the rest of the macroeconomy.

In our stylized model, individual firms – which are heterogeneous in their (permanent) productivity levels – produce output using labor as the only input. Importantly, we introduce the option of firms to conduct part of their production remotely. Following the empirical literature on work from home, remote work entails a trade off between a reduction in labor costs and declines in the efficiency of production.

On the one hand, existing studies suggests that remote work puts downward pressure on wage growth (see e.g. Barrero et al., 2022), reduces worker turnover and associated training and hiring costs (see e.g. Bloom et al., 2023b) but also decreases the need for office or production space lowering fixed overhead costs (see e.g. Barrero et al., 2023). On the other hand, it has been shown that (high enough rates of) remote work are associated with productivity declines (see e.g. Battiston et al., 2021; Yang et al., 2022; Emanuel and Harrington, 2023; Gibbs et al., 2023). These efficiency losses can stem from impeded communication, less effective mentoring and training or reductions in worker motivation and self-control.

Our stylized framework allows us to derive several analytical predictions about the optimal choice of firms' remote work rates and the implications for firm entry and exit.

[1] See e.g. Barrero et al. (2022, 2023); Bloom et al. (2023b); Battiston et al. (2021).

We show that exogenous increases (decreases) in the efficiency (cost) of remote work lead to a greater uptake of work from home arrangements, a rise in profitability and firm values. This is intuitive as production becomes either more efficient or cheaper. Importantly, our framework shows how firm values are linked to business entry and exit, forging a link between the latter two and remote work. On the one hand, greater firm values increase incentives of prospective businesses to start up and firm entry rises. On the other hand, higher profitability allows incumbent firms to operate more easily and, therefore, firm exit declines. As will become clear, the latter prediction holds only in partial equilibrium, assuming wages remain unchanged.

Next, we test these model predictions empirically making use of several micro-datasets. First, we draw on the American Time Use Survey (ATUS) to compute remote work rates as the share of days worked from home in all work days.[2] Second, we complement the information from ATUS with that in the Current Population Survey (CPS) in order to compute remote work rates at the industry level. Third, we use the Business Employment Dynamcis (BED) data as a source of quarterly information on business entry and exit. The key advantage of this dataset is its timely frequency with observations up to Q4 of 2022 at the time of writing this paper. Finally, for certain parts of our analysis, we also link the ATUS information to the Annual Social and Economic Supplement (ASEC) of the CPS which allows us to infer the size distribution of firms adopting remote work.

Using our linked data, we estimate a batch of panel regressions connecting changes in business entry and exit with adoptions of work from home rates across industries. We consider the "full" sample period between 2003 (the start our work from home information from ATUS) and 2022, but also single out the pre-pandemic period between 2003 and 2019. Controlling for time and industry fixed effects and a range of other controls, we document that – both in the full and pre-pandemic samples – larger increases in work from home rates are associated with both higher business entry as well as stronger business exit. While the former can be rationalized by our framework, the latter cannot. However, as mentioned earlier, our theoretical analysis holds in partial equilibrium. We study the general equilibrium (and macroeconomic) impact of changes in work from home in a richer, "generalized," model.

The generalized framework extends our initial theoretical analysis along several important dimensions. First, we allow for persistent stochastic fluctuations in firms' productivity levels. Second, we consider capital as a production factor and assume that its accumulation is subject to adjustment costs. Both these extensions affect the firm size and profit distributions and with them the the responsiveness of the macroeconomy to changes in work from home conditions. Third, we consider flexible labor supply, allowing workers to endogenously respond to remote work changes. Finally, we solve the model in

[2] In the Appendix, we show that our results are very similar when considering remote work more generally, i.e. not necessarily "just" from home.

general equilibrium.

We parameterize the generalized model to match key (pre-pandemic) features of U.S. data. Specifically, our model is made to match the strong "up-or-out" dynamics with high exit rates of young firms, but strong average growth of surviving business (see e.g. Haltiwanger et al., 2013). Next, to discipline the key margin of our framework – work from home decisions – we parameterize the speed with which production efficiency and labor costs decrease with more employees working remotely by matching two key moments in the data: a maximum productivity loss of fully remote work of 14 percent – a midpoint between the estimated values (see Barrero et al., 2023) – and an average pre-pandemic work from home rate of 4 percent which we estimate from ATUS data. The parameterized model does well in matching a range of other *untargetted* empirical moments related to capital investment rates, firm-level productivity dynamics as well as the extent of cost savings of remote work.

To *quantify* the macroeconomic impact of increased work from home arrangements we consider a counterfactual exercise in which we make remote work more efficient and less costly to match the post-pandemic experience of the U.S. economy. To discipline the relative strength of these two driving forces, we make our model match the post-pandemic increase in overall work from home rates and the relative change in remote work rates among large businesses. The intuition why the latter helps us identify productivity- vs cost-driven changes in remote work rests on the fact that work from home partly reduces fixed operating costs. Fixed costs are less of a concern for large businesses for which they represent a smaller fraction of sales. Therefore, while changes in the costs of remote work favor smaller firms, changes in the efficiency of work from home affect businesses of different sizes more uniformly.

Since remote work – and thus production – becomes more efficient and cheaper, firms increase output. They do so by favoring the now cheaper production factor and, therefore, the average capital-labor ratio declines. As predicted by our stylized model, these changes increase profitability and firm values, incentivizing firm entry and lowering business exit (especially of young, small, firms for which fixed costs are relatively more important). Since it is primarily less productive firms which shut down, reduced business exit softens firm selection and average firm-level productivity of surviving firms drops.

In general equilibrium, however, a larger mass of startups (and surviving businesses) raises labor demand, putting upward pressure on wages. This raises production costs for all businesses and, ultimately, firm exit increases. Therefore, our model explains why both firm entry and exit may be elevated in the post-pandemic period compared to prior to 2019 – consistent with the data. In addition, because firm selection tilts the size distribution towards smaller businesses, average size of entering and exiting firms is lower in the post-pandemic equilibrium. Using an extension of our panel regressions, we show that this too is consistent with the data. Indeed, industries which experienced the larges increases in remote work arrangements also saw the average size of entering and exiting firms drop the most.

As a final step in our analysis, we quantify the impact of these changes on aggregates. First, while average business-level productivity drops because of weaker firm selection, aggregate total factor productivity (TFP) rises. This happens because allocative efficiency improves. Intuitively, since our model features decreasing returns in production, a greater mass of smaller firms improves aggregate TFP. This, together with higher labor supply, leads to an increase in output. Higher output leads to a rise in household consumption despite elevated entry costs from more startups. Finally, we estimate that the changes which led to elevated work from home arrangements following the COVID-19 pandemic have raised household welfare by 0.5 percent.[3]

Our paper is related to two strands of the literature. First, it contributes to research studying remote work with several very recent papers analyzing the (post-)pandemic period (see e.g. Barrero et al., 2022, 2023; Decker and Haltiwanger, 2023; Hansen et al., 2023), but also earlier contributions (see e.g. Bloom et al., 2015). Complementary to our paper, Davis et al. (2024) model the household side of remote work tradeoffs and the impact on house prices, household income, wealth and on city structure. In contrast to these studies, we focus on the implications of remote work for business dynamism with a primary goal of quantifying their *macroeconomic* impact. Second, we connect to the literature on the macroeconomic impact of business dynamism – especially the influence of entry and exit (see e.g. Hopenhayn and Rogerson, 1993; Clementi and Palazzo, 2016; Sedláček and Sterk, 2017; Sedláček, 2020). To the best of our knowledge, however, we are the first to analyze the influence of optimal remote on business dynamism and the macroeconomy within these frameworks.

The rest of the paper is structured as follows. The next section lays out our stylized model and presents key theoretical results. Section 3 tests these theoretical predictions in the data. Sections 4 and 5 describe the generalized model, parameterize it and provide our main quantitative results. The final section concludes.

2 Stylized Model

The core purpose of this paper is to study the influence of work from home patterns on business dynamism and, in turn, on the macroeconomy. Towards this end, in this section we develop a tractable theory allowing us to derive sharp analytical predictions and to build intuition. Making use of several firm- and individual-level datasets, the next

[3]Note that our model is not particularly geared towards obtaining welfare gains from remote work. In particular, remote work decisions are made at the firm level and households take them as given. We also do not explicitly model additional benefits of remote work such as a decline in commuting time (i.e. increased leisure and/or work hours), benefits for home-production (see e.g. Barrero et al., 2023, for a discussion).

section tests our model predictions empirically. Section 4 then generalizes our theory into a fully fledged structural macroeconomic model of firm dynamics which we use the quantitatively evaluate the impact work from home patterns have on the macroeconomy.

2.1 Model

Consider a framework in which there is a continuum of firms, each producing a final good sold to the household for consumption. In what follows, time is discrete and we use upper-case letters to denote aggregates and lower-case letters for firm-level variables.

Production and costs. Individual firms produce output, y, using labor, n, as the only production factor. All businesses have the same production technology, but they differ in their productivity levels $z > 0$:

$$y(z) = zn^{\alpha}, \tag{1}$$

where $\alpha \in (0, 1)$ denote returns to scale and where firm-level productivity is assumed to be constant throughout firms' life-cycles.

Labor is supplied by the household for a take-home wage, W, which firms take as given. Moreover, firms must pay a per-worker resource cost, κ_n, representing additional (non-wage) labor costs such as worker training, office equipment and supplies, catering, subsidies for commuting costs or other employee benefits. Finally, in addition to labor costs, each period firms must also pay a fixed overhead cost, κ_o, in order to stay in operation. This cost represents items such as office rent or building maintenance, utility or insurance costs, council taxes etc.

Work from home. All firms have the possibility of having a fraction, $\omega \in [0, 1]$, of their employees work from home. There are both costs and benefits of remote work.[4]

On the one hand, work from home helps firms reduce their costs – both those related to non-wage labor costs, κ_n, and overhead costs, κ_o.[5] Remote work moderates labor costs (see e.g. Barrero et al., 2022) through a direct impact on the non-wage labor costs discussed above, but also because it can help reduce quit rates and associated turnover and training costs (see e.g. Bloom et al., 2023b). In addition to labor cost moderation, remote work also lowers overhead costs as firms require less production space and save on associated on-site production costs (see e.g. Barrero et al., 2023, for a discussion).

On the other hand, we assume that producing with a larger fraction of remote workers lowers firm-level productivity. Several studies show, in various settings, that fully remote

[4]In this section, we assume that the household takes ω as given.The generalized model of Section 4, endogenizes the household response to work from home patterns by allow for flexible labor supply.

[5]We abstract from direct impacts of work from home on wages – e.g. because businesses can recruit from low-wage areas. Our generalized model, however, allows for changes in remote work patterns to impact wages indirectly through general equilibrium effects.

work yields lower productivity than on-site work. These productivity losses of remote work occur because of impeded communication, less effective mentoring or management and reductions in worker motivation and self control (see e.g. Battiston et al., 2021; Yang et al., 2022; Emanuel and Harrington, 2023; Gibbs et al., 2023).[6]

We model the above effects by allowing firm productivity and (non-wage) labor and overhead costs to be affected by remote work. In particular, we assume that (i) firm productivity is affected by remote work according to $f(\omega) \in [0,1]$, with $f'(\omega) < 0$, and (ii) (non-wage) labor and overhead costs are impacted by work from home according to $g(\omega) \in [0,1]$, with $g'(\omega) < 0$.

Firm entry and exit. There is a continuum of potential entrants which are, ex-ante, identical. In order to enter the economy, potential startups must pay a fixed entry cost, κ_e, upon which they obtain a draw of their (fixed) idiosyncratic productivity. Firms draw their productivity from a common distribution described by a probability and cumulative distribution function $h_z(z)$ and $H_z(z)$, respectively.

All businesses are subject to an exogenous risk of shutting down, $\delta \in [0,1)$. In addition, businesses may choose to shut down endogenously. This happens if firm value, $v(z)$, falls below zero:

$$v(z) = \max_n \left\{ 0, \sum_{t=0}^{\infty} [\beta(1-\delta)]^t \pi(z) \right\} = \max_n \left\{ 0, \frac{\pi(z)}{1-\beta(1-\delta)} \right\}, \tag{2}$$

where $\beta \in (0,1)$ is a discount factor and where $\pi(z) = f(\omega)y(z) - Wn - g(\omega)(\kappa_n n + \kappa_o)$ are per-period profits. The above gives rise to an exit rule – a cutoff productivity, $\widetilde{z}$, below which firms choose to shut down. This cutoff productivity is implicitly defined by

$$\pi(\widetilde{z}) = f(\omega)y(\widetilde{z}) - Wn(\widetilde{z}) - g(\omega)(\kappa_n n(\widetilde{z}) + \kappa_o) = 0, \tag{3}$$

where we have made explicit that employment is an endogenous choice which depends on firms' productivity levels.

In this framework, the distribution of surviving firms is then given by

$$\mu(z) = \begin{cases} 0 & z < \widetilde{z}, \\ \frac{h_z(z)}{1-H_z(\widetilde{z})} & \text{if } z \geq \widetilde{z}. \end{cases} \tag{4}$$

The distribution $\mu(z)$ determines average firm-level and, in turn, aggregate produc-

[6] Studies of hybrid arrangements, i.e. partial work from home setups, find either no productivity effects or slight gains (see e.g. Bloom et al., 2015; Choudhury et al., 2021; Angelici and Profeta, 2023). While in reality firm-level productivity may rise for lower levels of ω before declining, in what follows we assume a monotone negative impact of remote work on productivity. This omission does not affect our results because – as will become clear – firms would always optimally choose levels of ω which imply productivity losses that exactly balance associated cost savings.

tivity. The mass of (entering) firms is then implicitly given by the following condition

$$\kappa_e = \int v(z)\mu(z)dz, \tag{5}$$

where we have assumed free entry.

Household, aggregates and equilibrium. To keep this part of the analysis concise, we defer the description of the household, aggregates and a formal definition of the equilibrium to the Appendix. Moreover, the Appendix explains how changes in firm values affect the exit threshold, $\widetilde{z}$, and, in turn, firm exit, entry, the distribution of surviving businesses, average and aggregate productivity, output and consumption.

2.2 Theoretical Results

In what follows, we analytically study optimal work from home choices, ω^*, their impact on the firm distribution and, in turn, on aggregates. We defer all proofs to the Appendix.

Work from home and business entry and exit. The following proposition summarizes firms' optimal work from home decisions and their relation to firm productivity.

PROPOSITION **1** (Optimal work from home rates)
In the framework described above and for interior solutions, optimal work from home rates, ω^*, satisfy the following

a) if $\kappa_o = 0$, then ω^* is common across firms and implicitly given by

$$\frac{f'(\omega^*)}{f(\omega^*)}\frac{g(\omega^*)}{g'(\omega^*)} = \alpha\frac{g(\omega^*)\kappa_n}{W + g(\omega^*)\kappa_n},$$

b) if $\kappa_o > 0$, then

$$\frac{\partial \omega^*}{\partial z} < 0.$$

The first part of Proposition 1 states that without fixed overhead costs, all businesses optimally choose the same level of work from home rates.[7] The intuition is that firms choose work from home rates to balance the associated marginal cost (efficiency reductions) benefits (reduced labor costs). This mimics the tradeoff of optimal labor demand which, in turn, is governed by the returns to scale parameter, α. The resulting tradeoff for remote work is, therefore, governed by the returns to scale parameter and adjusted for by the share of costs which can be reduced by remote work.

[7]Note that interior solutions for ω^* require $f''(\omega) \leq 0$ and $g''(\omega) \geq 0$. Intuitively, costs must (initially) decrease faster than productivity in order for firms to choose non-zero work from home rates.

The second part of Proposition 1 states that with positive overhead costs, optimal work from home rates decrease with firm productivity and (in this framework) with firm size. Intuitively, for less productive (smaller) firms, fixed overhead costs represent a larger share of their overall costs. This provides small firms with greater incentives to save on such costs by shifting more of their workforce off-site.

Changes to work from home and firm entry and exit. We now analyze the impact changes in work from home rates may have on firm entry and exit. Towards this end, let us denote $\widetilde{f}$ and $\widetilde{g}$ as parameters of $f(\omega)$ and $g(\omega)$ which affect the speed at which productivity losses and cost savings accrue with remote work:

$$\frac{\partial f(\omega;\widetilde{f})}{\partial \widetilde{f}} < 0, \quad \frac{\partial^2 f(\omega;\widetilde{f})}{\partial\omega\partial \widetilde{f}} > 0 \;\text{ and }\; \frac{\partial g(\omega;\widetilde{g})}{\partial \widetilde{g}} < 0, \quad \frac{\partial^2 g(\omega;\widetilde{g})}{\partial\omega\partial \widetilde{g}} > 0.$$

In this sense, the parameters $\widetilde{f}$ and $\widetilde{g}$ can be thought of as summarizing the efficiency of remote work technologies and their relative price.[8] The following proposition describes how exogenous changes to $\widetilde{f}$ and $\widetilde{g}$ impact optimal work from home rates, firm entry and exit.

Proposition 2 (Changes in remote work and firm dynamics)
Assuming internal optimal work from home rates, ω^*, exogenous changes in the parameters $\widetilde{f}$ and $\widetilde{g}$ impact the following firm-level outcomes:

a) Work from home rates:

$$\frac{\partial\omega^*}{\partial\widetilde{f}} < 0, \quad \frac{\partial\omega^*}{\partial\widetilde{g}} > 0,$$

b) Firm profits:

$$\frac{\partial\pi}{\partial\widetilde{f}} < 0, \quad \frac{\partial\pi}{\partial\widetilde{g}} > 0,$$

c) Exit threshold:

$$\frac{\partial\widetilde{z}}{\partial\widetilde{f}} > 0, \quad \frac{\partial\widetilde{z}}{\partial\widetilde{g}} < 0.$$

d) Impact semi-elasticities:

$$\frac{\partial \ln\pi}{\partial\widetilde{g}} > \frac{\partial \ln\pi}{\partial\widetilde{f}}, \frac{\partial \ln\widetilde{z}}{\partial\widetilde{g}} > \frac{\partial \ln\widetilde{z}}{\partial\widetilde{f}}.$$

Parts a) to c) of Proposition 2 describe why and how work from home rates may be

[8] Note that what is important for firms' decisions is the efficiency and price of remote work *perceived* by individual businesses. This allows $\widetilde{f}$ and $\widetilde{g}$ to also capture, in a reduced for way, changes in productivity perceptions or the stigma associated with remote work (see e.g. Barrero et al., 2023).

connected to firm entry and exit.[9] Intuitively, they show that changes in the mapping of remote work rates to productivity losses and/or cost savings necessarily impact firms' optimal work from home rates (Part a). This, in turn, has an effect on firm profits (Part b), exit decisions (Part c) and via the free entry condition (36) also firm entry. Therefore, (in partial equilibrium) cheaper or more efficient work from home practices raise profits, firm values, lower exit and increase entry.

Finally, Part d) of Proposition 2 states that changes driven by cost savings have a stronger impact on business dynamism than those driven by productivity losses. The intuition rests on the respective shapes of f and g. In particular, in order for businesses to optimally choose internal remote work rates, it must be that costs initially fall faster than productivity. This, in turn, implies a larger effect on profits and the exit threshold for a given cost-driven change in optimal remote work rates compared to the same productivity-driven change.

Before moving on, let us note that while our theoretical results establish a connection between remote work choices and business entry and exit, they do so in partial equilibrium. In reality, wages may adjust to changes in the efficiency and price of remote work and this will impact the overall response of firm entry and exit. We investigate this – both empirically and theoretically – in the following sections.

3 Empirical Evidence

Having established a theoretical link between remote work and business entry and exit, we now turn to empirical evidence on these patterns. We first describe work from home rates in the cross-section and how they have evolved over time. Next, we estimate the relationship between work from home and business entry and exit.

3.1 Data and Definitions

Our analysis combines information on individuals and businesses. In what follows, we describe the main data sources as well as the methodology of constructing our key variable of interest: working from home rates.

Work from Home. We rely on the American Time Use Survey (ATUS) which is conducted by the Bureau of Labor Statistics and provides monthly information (starting in January 2003) on how individuals in the U.S. allocate their time among various activities. The sample of households is connected to the Current Population Survey (CPS) allowing

[9] Our theoretical results relate to partial equilibrium outcomes, assuming a fixed wage. We consider general equilibrium outcomes in Section 4.

us to link individuals' time allocation data to other information, such as the industry they work in.[10]

For our purposes, we focus on individuals' time allocated to working and its reported location. In particular, following Barrero et al. (2023) we count working days of individual j, d_j, as those in which individuals devote at least 6 hours to work in their main job.[11] Analogously, we define days worked from home, d_j^{home}, as those in which individuals spend at least 6 hours working from home in their main job. A key object of interest is then the *work from home rate* in period t, ω_t, which we define as the number of days spent working at home, d_t^{home} as a fraction of all work days, d_t.

We compute work from home rates at the industry level. Towards this end, we complement information from ATUS with industry classification data from the CPS. Anticipating the quarterly frequency of our business dynamism information (described below), we define work from home rates in industry i and quarter t as the sum of all days worked from home by individuals working in industry i relative to the total number of work days in that industry:[12]

$$\omega_{i,t} = \frac{\sum_{j=1}^{J_{i,t}} d_{j,\tau}^{home}}{\sum_{j=1}^{J_{i,t}} d_{j,\tau}}, \tag{6}$$

where $J_{i,t}$ is the number of individuals reporting in industry i in quarter t.

Business entry and exit. To measure entry and exit of businesses, we use the Business Employment Dynamics (BED) dataset of the Bureau of Labor Statistics. This dataset is generated from the Quarterly Census of Employment and Wages and offers quarterly information on employment at the establishment level covering approximately 98 percent of all employment in the U.S. economy.[13] A key advantage of this dataset is its relatively timely nature with the latest data – at the time of writing this paper – running all the way to Q4 2022. This data, therefore, allows us to analyze the pandemic and post-pandemic periods.[14]

[10]The ATUS targets households which have completed their final (eighth) month of the CPS. From each of the selected households, a random individual aged 15 and over is chosen to participate in ATUS. The questionnaire asks information about the respondent's previous day and is conducted only once for each individual. For more details on ATUS, see Hamermesh et al. (2005).

[11]To define our baseline measure of working from home, we focus on workers with minimum real annual earnings of $20,000 (counted as 52 times average weekly earnings, deflated by the Personal Consumption Index). The Appendix shows that results are similar when considering "work-outside-workplace", i.e. anywhere but the respondent's workplace. Moreover, similar results are obtained when defining working from home as the fraction of hours worked from home *at the individual level*. Intuitively, this is because most individuals either spend entire days working at home or at their workplace.

[12]Since the ATUS interviews individuals in outgoing waves of the CPS and asks time allocation information for only one day, counting days is the same as counting individuals.

[13]The BED excludes self-employed individuals, government institutions and some non-profit organizations.

[14]An alternative popular datasource for business dynamism is the Business Dynamic Statistics (BDS) of the Census Bureau. While there exist differences between the BDS and the BED, the numbers of establishments as well as their employment sizes typically comove strongly across the two datasets (see

Establishment entry – formally called "births" in the BED – are units which record positive employment for the first time in a given quarter and which exclude (seasonal) re-openings of businesses. Symmetrically, establishment exit – formally called "deaths" in the BED – are units with zero employment which exclude temporary closings of businesses.[15]

As with working from home, we are interested in the industry-level patterns of business entry and exit. For our purposes, the BED and QCEW have information at the super-sector level. Due to low within-industry sample sizes we exclude "natural resources and mining" and "financial activities", which leaves us with quarterly information between 2003Q1-2022Q4 for 10 industries.[16]

3.2 Empirical Analysis

In what follows, we first provide descriptive statistics on how work from home evolved over time and in the cross-section. We then move on to estimating the relationship between work from home rates and business entry and exit.

Work from home: Heterogeneity across sectors and firm sizes. In the period between 2003 and 2019, the average work from home rate was just over 4% in the U.S. economy. However, this value hides a large amount of heterogeneity both across different sectors and over time.

Table 1 summarizes the heterogeneity in work from home across sectors for our pre-pandemic sample. Intuitively, Transportation and Warehousing or Construction have the lowest work from home rates. In contrast, service industries (Financial activities, Information, Profession and Business Services) have work from home rates as high as 14%, i.e. more than quadruple that of Construction or Transportation.[17]

In addition, linking information on individual work from home patterns from ATUS to the Current Population Survey (CPS) and, in particular, the Annual Social and Economic Supplement (ASEC) allows us to infer the size distribution of firms for which individuals

e.g. Decker and Haltiwanger, 2023, for a discussion). In the Appendix, we provide a comparison between the BDS and the BED showing that for our purposes they are similar in the overlapping periods.

[15]To determine whether a shut down is a death or temporary closure, the BLS requires establishments to report zero employment for four consecutive quarters before it classifies it as a death. Such establishment deaths are then "back-dated" to the relevant quarter when they occurred. Moreover, the Appendix shows that our results are similar when using establishment openings and closings as opposed to the stricter births and deaths.

[16]Note that data on deaths runs only to 2022Q2. The Appendix shows that we obtain similar results when using a more disaggregated 2-digit NAICS classification. However, at this level of disaggregation, the BED has only information on openings (births and seasonal re-openings) and closings (deaths and temporary closures).

[17]Work from home patterns differ across industries not only on average, but also in terms of the speed at which they change over time. For instance, while the Utility industry experienced more than a doubling in its work from home rate over the course of 2003-2019 (albeit from a very low starting point), work from home actually became *less* frequent over time in the Leisure and hospitality industry.

Table 1: Work from home rate: Industry heterogeneity

Industry	WFH	Industry	WFH
Construction	1.5	Other Services	4.6
Educational and Health Services	3.1	Professional and Business Services	8.6
Financial Activities	6.7	Public Administration	2.0
Information	8.8	Retail Trade	1.5
Leisure and Hospitality	1.3	Transportation and Warehousing	1.7
Manufacturing	2.9	Utility	0.8
Natural Resources and Mining	5.3	Wholesale Trade	5.0

Note: The table reports work from home rates (in %) across super-sectors for the period between 2003Q1 and 2019Q4.

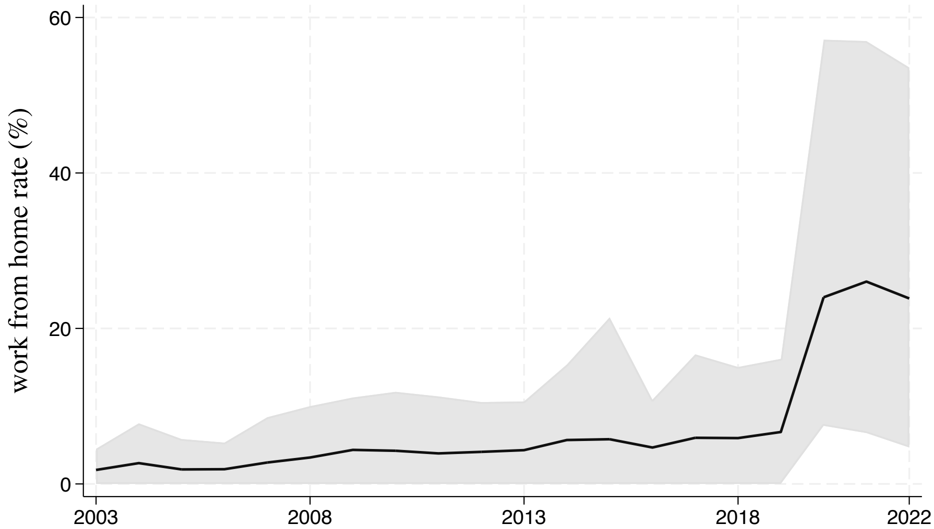
in ATUS report working remotely. According to this data, remote work was somewhat less common in larger firms between 2003-2019. Specifically, while average work from home rates were about 4.1% among all businesses, they were 3.7% for firms with more than 100 employees. Recall that through the lens of our theory, this is consistent with the possibility of alleviating a fraction of firms' (non-zero) fixed costs through remote work.

Work from home: Changes over time. Figure 1 shows how work from home rates evolved over time. The solid black line depicts the *aggregate* work from home rate, As is clear from the figure, work from home has been on a gradually increasing trend from the start of our sample. In particular, average remote work rates increased from about 1.8% in 2003 to 6.7% in 2019. The shaded areas then indicate the range of work from home rates across industries. As is apparent from the figure, there is a large degree of sectoral heterogeneity throughout our sample.

Across all sectors, however, the COVID-19 pandemic had a profound impact on remote work, inducing a dramatic increase in such flexible work arrangements. In 2020, the first year of the pandemic, work from home rates jumped to 24%. While the most recent time periods have seen a slight reversal, work from home rates remain substantially elevated compared to the pre-pandemic period. Specifically, the average remote work rate in 2022 was 23%. All these patterns are consistent with evidence from other sources for the U.S. economy, as well as with international data (see e.g. Barrero et al., 2023; Bloom et al., 2023a; Decker and Haltiwanger, 2023).

Work from home and business entry and exit: Raw data. We now turn to the link between work from home rates and business entry and exit. First, Figure 2 shows how changes in business entry and exit relate to work from home patterns across industries. In particular, percentage point changes in industry-level work from home rates are shown on the horizontal axis, while the vertical axis depicts the corresponding percent changes in the number of entrants and exiters. In both cases, we consider separately the full

Figure 1: Work from home rate: Changes over time



Note: The figure shows work from home rates – computed from ATUS as described in the main text – over time for the aggregate economy (solid black line) and the range of values across industries (shaded area).

sample (2003-2022) and the pre-pandemic period (2003-2019).[18]

The figure shows that increases in work from home rates are associated with both higher entry and exit of businesses. Moreover, this pattern is not a pandemic-only phenomenon. In fact, the relationship is somewhat weaker during the pandemic which saw unprecedented increases in work from home rates.

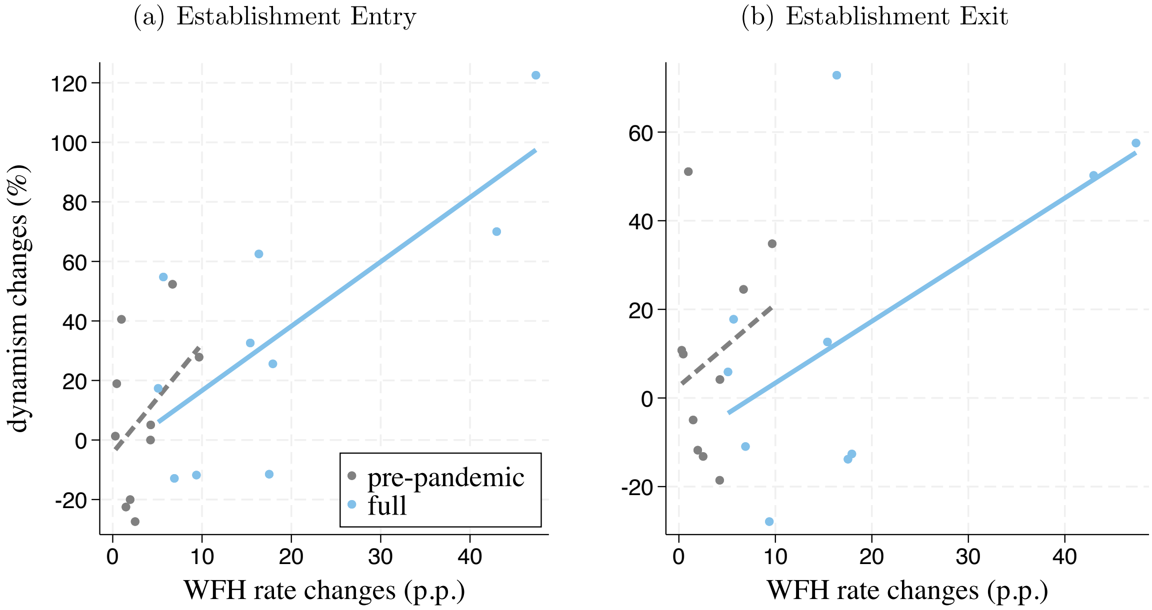
Our theoretical results from the previous section rationalize the positive relationship between changes in remote work rates and business entry. Specifically, as remote work becomes more attractive, this raises profits and encourages business entry. For the same reasons our stylized model also predicts a drop in business exit which is at odds with the empirical evidence in Figure 2.

However, our theoretical results pertain to partial equilibrium changes only. In reality, other factors – including general equilibrium changes in the wage rate – may overturn these partial equilibrium predictions. To consider such other factors, we extend our analysis in two ways. First, the paragraphs below estimate the relationship between entry, exit and work from home rates while controlling for a range of potential contributing factors. Second, Section 4 considers an extended theoretical model in general equilibrium.

Work from home and business entry and exit: Estimation. To formally test whether work from home patterns are related to business entry and exit, we use panel

[18]We compute changes as the difference in the respective values at the end of the pre-pandemic period (average of 2018Q1-2019Q4) or the full sample (average of 2021Q1-2022Q4) relative to the start of our sample (average of 2003Q1-2004Q4).

Figure 2: Work from Home and Business Dynamism: Changes across Industries



Note: The figure depicts super-sector changes in work from home rates on the horizontal axis (in p.p.) and (percent) changes in the number of entrants (Panel a) and exiters (Panel b). Work from home rates are estimated from ATUS as described in the main text. Business entry and exit data is taken from the BED. Both panels show data for the pre-pandemic sample (2003-2019) and the full sample (2003-2022).

regressions. This allows us to not only utilize more time-series variation, but also to control for factors that may influence business entry and exit independently from work from home changes. In particular, we estimate the following regression:

$$y_{i,t} = \delta_i + \delta_t + \beta\overline{\omega}_{i,t} + \Gamma X_{i,t} + \epsilon_{i,t}, \tag{7}$$

where $y_{i,t}$ is a measure of business entry or exit in industry i and period t, δ_i are industry fixed effects, δ_t are time fixed effects, $X_{i,t}$ is a set of control variables and $\overline{\omega}^L_{i,t} = 1/(L+1)\sum_{l=0}^{L}\omega_{i,t-l}$ are time-varying moving averages of work from home rates. Coefficient β is the primary object of interest as it provides a concise summary of the potentially dynamic (lagged) effects of working from home rates on business dynamism.[19]

In estimating β, we control for a range of variables. First, $X_{i,t}$ includes lags of our (average) work from home measure, $\overline{\omega}$. Second, in addition to controlling for industry differences through fixed effects, δ_i, and aggregate trends through time fixed effects, δ_t, we also include industry-specific real output growth rates, $g_{i,t}$, taken from the Bureau of Economic Analysis. Finally, as before, we consider two sample periods for our specifications: "pre-pandemic" sample and "full" sample.

Table 2 shows that even after controlling for a range of other factors, changes in both

[19]In our baseline specification we use $L = 4$. The Appendix provides robustness exercises with respect to L.

Table 2: Working from home and business dynamism: Regression results

	Pre-pandemic		Full sample	
	Entry	Exit	Entry	Exit
Average WFH rate, β	1.414***	1.214***	1.400***	0.941***
	(0.218)	(0.240)	(0.117)	(0.120)
Industry & time f.e.	✓	✓	✓	✓
Controls	✓	✓	✓	✓
R-squared	0.502	0.405	0.705	0.529
# observations	590	590	710	690

Note: The table reports results from estimating (7). The first two columns report estimates using the pre-pandemic period (2003Q1-2019Q4) only, while the last two columns report results for our entire sample period (2003Q1-2022Q4). Controls include lagged values of the dependent variable and industry-level real output growth rates.

business entry and exit are positively related to changes in remote work rates. Moreover, these are not only statistically significant, but also economically strong. In particular, a one-percentage point increase in work from home rates is estimated to raise entry (and exit) by 1.4 (1.2) percent in the pre-pandemic period (and similarly in the full sample).

To put these values into perspective, note that the number of entrants and exiters fell by about 20-30 percent during our pre-pandemic period. This is consistent with mounting evidence on the slowing of business dynamism (see e.g. Decker et al., 2016). As we discuss above, during the period remote work rates increased on average by about 5 percentage point. Our estimates from Table 2 suggest that such an increase in work from home may have offset the drop in entry and exit by about 7 percentage points, i.e. about a quarter of the observed decline. We address this same question – what is the impact of rising work from home rates on business entry and exit (and, in turn, the macroeconomy) – quantitatively in the next section using our generalized model.

4 Generalized Model

In this section, we generalize the theoretical model presented in Section 2 and parameterize it to match important features of U.S. data. Then, we use this generalized model as a laboratory in which to quantitatively evaluate the impact increases in work from home rates – documented in the previous section – have had on the U.S. macroeconomy.

4.1 Environment

The generalized model retains the structure of our stylized framework, but extends it along several important dimensions. First, we allow firm-level productivity to fluctuate stochastically over time. Second, we allow firms to invest into physical capital, subject to adjustment costs. Both these extensions will affect the distribution of firms in the model and, in turn, the responsiveness of the economy to changes in parameters – including those governing the productivity losses and cost savings associated with remote work. Third, we allow for flexible labor supply which endogenizes the household's response to work from home decisions made by individual firms. Finally, we solve our model in general equilibrium, allowing equilibrium prices to respond to any changes which may affect remote work decisions.

As before, we will use upper-case letters to denote aggregates and lower-case letters to denote firm-level variables. While interesting in its own right, we will not use our framework to study aggregate fluctuations. Therefore, all aggregates will be fixed in our model. Firm-level variables, however, will in general not be constant, reflecting changes in firm-specific (endogenous and exogenous) state variables. Therefore, whenever necessary we denote time with a subscript t.

Production. Firms produce output using labor, n_t, and capital, k_t. They do so according to the following production function:

$$y_t = f(\omega_t) z_t \left(n_t^{\alpha} k_t^{1-\alpha}\right)^{\theta}, \tag{8}$$

where $\alpha \in (0,1)$ and $\theta \in (0,1)$ are common across all firms and where z_t is firm-specific productivity which evolves according to the following law of motion:

$$\ln z_t = \underline{z}(1-\rho) + \rho \ln z_{t-1} + \epsilon_t, \tag{9}$$

where $\underline{z}$ is (unconditional) mean productivity, $\rho \in (0,1)$ is the persistence of firm-level productivity and where ϵ_t are productivity shocks which are distributed identically and independently across firms and over time according to the distribution function H_z with zero mean and dispersion σ_z. As in our stylized model, $f(\omega)$, represents the efficiency losses associated with remote work.

While labor is hired on the spot market from the household, firms accumulate capital subject to adjustment costs. In particular, we assume that investing x_t into capital accumulation comes at a cost $\zeta(x_t, k_t)$. The stock of firm-level capital then evolves according to the following law of motion:

$$k_{t+1} = x_t + (1-\delta_k) k_t, \tag{10}$$

where $\delta_k \in (0,1)$ is the capital depreciation rate and where we assume that capital becomes productive only in the next period.

Finally, in order to produce, firms must pay a per-period fixed overhead cost, κ_o. We assume that these costs are stochastic, distributed identically and independently over time and across firms according to the cumulative distribution function H_κ with mean

μ_κ and dispersion σ_κ.

As in our stylized model, we assume that firms can affect the average level of their fixed overhead costs with work from home choices, summarized by the function $g(\omega)$. However, we assume that firms do note have control over the stochastic part of these costs. As will become clear, it will be convenient to separate overhead costs into their average and stochastic components, $\widetilde{\kappa}_o = \kappa_o - \mu_\kappa$, where $\widetilde{\kappa}_o$ are distributed according to H_κ with zero mean and dispersion σ_κ.

Firm Values and Optimal Decisions. In our framework, firms have several choices to make. First, every period, businesses choose whether or not to stay in operation and – if they decide to continue –how many workers to hire and what amount of resources to devote to capital accumulation. Second, every period, firms choose what fraction of their employees to let work from home.

Formally, businesses make their decisions in order to maximize the net present value of current and all future profits. In particular, the beginning-of-period value of a businesses in operation is given by

$$v(z_t, k_t) = \max_{n_t, \omega_t, x_t} \left\{ \pi_t + \beta(1-\delta) \int \max\left[\mathbb{E}_t v^x(z_{t+1}, k_{t+1}), \mathbb{E}_t v(z_{t+1}, k_{t+1}) - \widetilde{\kappa}_o\right] dH_\kappa(\widetilde{\kappa}_o) \right\}, \tag{11}$$

where $\pi_t = f(\omega_t) z_t \left(n_t^\alpha k_t^{1-\alpha}\right)^\theta - W n_t - g(\omega_t)(\kappa_n n_t + \mu_\kappa) - x_t - \zeta(x_t, k_t)$ are per-period profits, $\beta \in (0,1)$ is the discount factor, $\delta \in [0,1)$ is an exogenous rate of exit, $\mathbb{E}$ is an expectation operator with respect to the evolution of firm-level productivity. The exit value, $v^x(z,k)$, is given by

$$v^x(z_t, k_t) = k_t(1-\delta_k) - g(-k_t(1-\delta_k), k_t), \tag{12}$$

where firms obtain value from selling their stock of capital, but have to take into account the adjustment costs of doing so.

Firm Entry. We assume that there is a continuum of potential entrants. In order to start up, potential entrants must pay a fixed entry cost, κ_e, upon which they obtain a random draw of firm level productivity from the distribution $H_z(z)$. In addition, we impose that startups enter with no workers and no capital. Assuming free entry, the following condition implicitly pins down the mass of entrants, M:

$$\kappa_e = \int_z v(z,0) dH_z(z). \tag{13}$$

Representative Household. We assume a representative household which owns all businesses in the economy and optimally chooses aggregate consumption, C, and labor,

N. Formally, per-period utility is given by

$$\ln C - \upsilon N, \tag{14}$$

where $\upsilon > 0$ is the disutility of labor and where we have assumed labor to be indivisible following the tradition of Hansen (1985) and Rogerson (1988). The representative household maximizes the expected present value of life-time utility subject to its budget constraint:

$$C = WN + \Pi, \tag{15}$$

where, normalizing the aggregate price level $P = 1$, real aggregate profits are given by Π. The resulting optimal labor supply condition takes on the familiar form:

$$W = \upsilon C. \tag{16}$$

Aggregation. Using $\mu(z, k)$ to denote the distribution of firms, the following conditions describe goods and labor market clearing:

$$Y = \int\int y_t \mu(z,k) dz dk, \tag{17}$$

$$N = \int\int n_t \mu(z,k) dz dk. \tag{18}$$

Finally, the aggregate resource constraint is given by

$$Y = C + M\kappa_e + \int\int \left[\zeta(x_t, k_t) + g(\omega_t)(\kappa_n n_t + \mu_\kappa) + \widetilde{\kappa}_o\right] \mu(z,k) dz dk, \tag{19}$$

where aggregate output is used for consumption and all paid costs. The latter include entry costs, capital adjustment, non-wage labor costs and overhead costs. We defer a formal definition of the equilibrium to the Appendix.

4.2 Parametrization and Model Performance

To parameterize our model, we consider a period length of one year and we focus on the pre-pandemic period of 2003 to 2019. All model parameters are summarized in Table 3.

Common choices and normalizations. We set the discount factor to $\beta = 0.96$, reflecting a roughly 4% annual interest rate. The production function parameters are given by $\alpha = 0.65$ and $\theta = 0.9$. While the former mimics the observed labor share in income, the latter falls within the span of control values estimated in the data and commonly used in the literature (see e.g. Basu and Fernald, 1997; Clementi and Palazzo, 2016). We set the capital depreciation rate to 8% per year which lies in between values used in the literature (see e.g. Cooper and Haltiwanger, 2006; Clementi and Palazzo, 2016).

Finally, we set the disutility of labor υ such that the wage rate is normalized to $W = 1$. Similarly, we assume the entry cost κ_e is such that the mass of entrants is normalized to $M = 1$.

Functional forms. To bring our model to the data, we need to assume particular functional forms for the productivity loss and cost saving functions related to remote work, $f(\omega)$ and $g(\omega)$. Towards this end, we follow León-Ledesma and Satchi (2019) in their analysis of technology adjustment functions and specify both f and g as versions of exponential functions. As explained in Section 2 already, in order to allow for interior solutions to optimal work from home rates, we require that $f'' \leq 0$ and $g'' \geq 0$. Taking these together, we assume the following functional forms:

$$f = \exp\left(-\frac{\widetilde{f}}{2}\omega^2\right), \tag{20}$$

$$g = 1 - \exp\left(-\frac{\widetilde{g}}{2}(1-\omega)^2\right) + \exp\left(-\frac{\widetilde{g}}{2}\right). \tag{21}$$

The above specification ensures several important properties. First, fully on-site production entails no productivity losses or cost savings, $f(0) = g(0) = 1$. Second, both functions are decreasing in work from home rates, i.e. $f' < 0$ and $g' < 0$. Third, these functional forms allow for interior optimal work from home rates, i.e. $f'' \leq 0$ and $g'' \geq 0$.

Finally, note that the parameters $\widetilde{f}$ and $\widetilde{g}$ control the speed with which changes in work from home impact firm productivity and cost savings, respectively. As such, these will be crucial in determining our quantitative results and we describe how we discipline them next.

In addition to specifying how remote work affects production, we also need to make a stand on the form of capital adjustment costs, $\zeta(x, k)$. Towards this end, we follow Cooper and Haltiwanger (2006) and assume

$$\zeta(x, k) = \zeta_0(x)k + \frac{\zeta_1}{2}\left(\frac{x}{k}\right)^2 k, \tag{22}$$

where $\zeta_0(x) = \zeta_0$ whenever investment, x, is non-zero and $\zeta_0(x) = 0$ otherwise.

Indirect inference. The remainder of the parameters are set to match a range of business dynamism and work from home moments in the data. For the former, we make use of BED data on establishment size and exit rates. For the latter, we employ our remote work rate measures from ATUS.

While all model parameters affect the behavior of the entire model, we discuss the

Table 3: Parameter values and targeted moments

	Parameter	Value	Target/Source	Data	Model
β	Discount factor	0.96	Interest rate of approx. 4%		
α	Labor elasticity of output	0.65	Labor share in income of approx. 65%		
θ	Returns to scale	0.90	Basu, Fernald (1997) estimate		
δ_k	Capital depreciation	0.08	Cooper, Haltiwanger (2006)		
υ	Disutility of labor	0.005	Normalization, $W = 1$		
κ_e	Entry cost	3.1	Normalization, $M = 1$		
$\widetilde{f}$	Speed of remote work productivity losses	0.302	Productivity loss of fully remote work, Battiston et al. (2021)	14%	14%
$\widetilde{g}$	Speed of remote work cost savings	0.143	Average work from home rate, ATUS	4.1%	4.2%
κ_n	Non-wage labor costs	0.13	Average work from home rate of 100+ firms, ATUS & ASEC	3.7%	3.0%
$\underline{z}$	Mean productivity	0.085	Average establishment size, BED	15.4	15.3
ρ	Productivity persistence	0.718	Establishment size life-cycle profile, BED	see Figure 3	
σ_z	Productivity shock dispersion	0.210	Establishment size life-cycle profile, BED	see Figure 3	
ζ_0	Capital adjustment costs, fixed	0.001	Establishment size life-cycle profile, BED	see Figure 3	
ζ_1	Capital adjustment costs, variable	0.456	Establishment size life-cycle profile, BED	see Figure 3	
μ_κ	Overhead costs, mean	1.07	Establishment exit life-cycle profile, BED	see Figure 3	
σ_κ	Overhead costs, dispersion	2.45	Establishment exit life-cycle profile, BED	see Figure 3	

Note: The table presents values for all model parameters. The first three columns describe each parameter and its parameterized value, while the last two columns indicate the most relevant target or data source.

targeted moments in relation to the parameters to which they are tied the most. Specifically, there are 10 remaining parameters: mean firm-level productivity, its persistence and dispersion ($\underline{z}$, ρ, σ_z), the mean and dispersion of fixed overhead cost (μ_κ, σ_κ), capital adjustment cost parameters (ζ_0 and ζ_1), parameters controlling the speed of productivity declines and cost savings of remote work ($\widetilde{f}$, $\widetilde{g}$) and the level of non-wage labor costs (κ_n).

The productivity parameters and those of capital adjustment costs are closely linked to business growth rates and average establishment size. Therefore, we target average size and the life-cycle profile of establishment size from startups (age 0) to age 20 taken from the BED and averaged over the years 2003 and 2019.[20]

Next, overhead cost parameters are tied to patterns of firm exit. Therefore, using the same data source as for establishment size, we target the life-cycle profile of exit rates between the ages 1 and 20.[21]

Finally, we need to set the work from home parameters in our model. To determine the speed of productivity declines induced by remote work, $\widetilde{f}$, we target the productivity loss of fully remote production estimated in the data. While detailed research in this area is still relatively rare, the few existing studies put this value in the range of about $8 - 19\%$ (see Battiston et al., 2021; Yang et al., 2022; Emanuel and Harrington, 2023; Gibbs et al., 2023). Therefore, in our baseline specification we target the midpoint of these estimates, 14%. The parameter $\widetilde{g}$ controls the speed of cost savings from remote work. For a given value of $\widetilde{f}$, the parameter $\widetilde{g}$, disciplines the cost and benefit trade-off inherent to optimal work from home rates. Hence, we target average work from home rates estimated from ATUS data between the years 2003 and 2019. The last parameter determines the level of non-wage labor costs, κ_n. To pin this parameter down, we target the work from home rates of large firms.[22]

Practically, we compute the selected model-generated moments and compare them to their respective empirical counterparts and minimize the following loss function:

$$\min \sum_j \left(\frac{\text{model(j)} - \text{data(j)}}{\text{data(j)}} \right)^2,$$

where j indicates a given moment. Note that our model is over-identified as we are estimating 10 parameters using 21 moments (10 firm size moments, 8 firm exit moments and 3 work from home moments).

[20] Since the BED starts in 1992, the fife-cycle information for establishments in the age group of 6-10 years is from 2004 to 2019, for ages 11-15 is from 2009 to 2019, and for the age group 16-20 it is from 2014 to 2019.

[21] Startups, by construction, have 0 exit rates as firm shut downs are not observed within the first year.

[22] Intuitively, given all other parameters, κ_n controls the relative importance of reductions in fixed costs when choosing remote work rates (e.g. with $\kappa_n = 0$ remote work only reduces fixed costs). As explained in Section 2, fixed cost reductions are key for generating heterogeneity in remote work rates across the firm size distribution.

Model performance. Table 3 and Figure 3 show the targeted moments and their model counterparts. In addition, our model is consistent with a range of *untargeted* moments and estimates in the literature.

First, while we targeted average establishment size and its life-cycle growth in terms of employment, our model is also consistent with capital investment patterns. In particular, Cooper and Haltiwanger (2006) estimate average investment rates at around 12% and average inaction rates (investment rates between −1% and 1%) of about 8%. Our model predicts these values to be, respectively, 13% and 7%.[23]

Second, in addition to matching average patterns, our model also does reasonably well at matching dispersion moments. Specifically, Cooper and Haltiwanger (2006) report the dispersion of investment rates to be 0.34. Our model predicts this value to be 0.4.[24]

Third, the implied values of persistence and volatility of firm-specific productivity are close to empirical estimates in existing studies. For instance, Foster et al. (2008) estimate persistence of firm-specific TFP to lie between 0.75 and 0.81. The standard deviation of such productivity shocks is then estimated to fall within the range of 0.21 and 0.26. Our parameterization strategy yields a persistence parameter of 0.72 and a standard deviation of productivity shocks of 0.21.

Finally, let us provide a sense of the magnitude of the productivity losses and cost savings implied by our parameterization. In our baseline economy, an average firm which has 4% of its employees working remotely faces an efficiency loss of just 0.02%. On the other hand, this average firm saves 0.5% on its labor (and overhead) costs. These results are broadly consistent with the empirical evidence that partial remote work arrangements come with essentially no productivity loss (see Barrero et al., 2023) and that flexible work arrangements can reduce wage pressures by about 1 percent (see Barrero et al., 2022).

5 Macroeconomic Impact of Work from Home

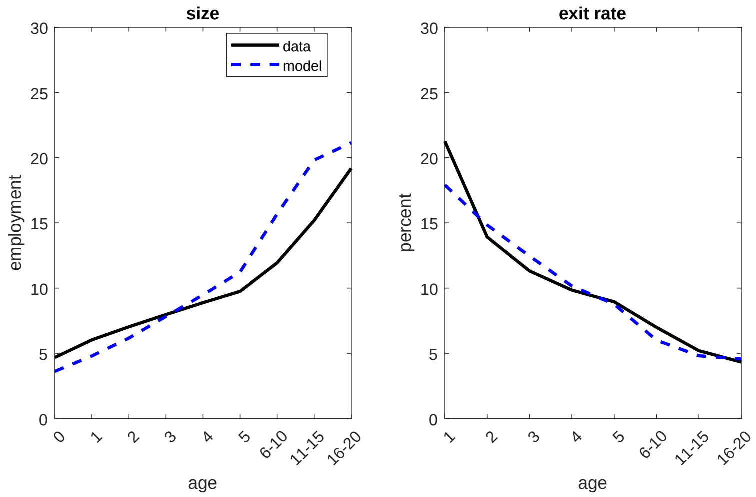
In this section, we use our parameterized model to quantitatively evaluate how changes in work from home patterns impact business dynamism and, in turn, the macroeconomy. In our baseline analysis, we leave out the COVID-19 period of 2020 and 2021 and, instead, focus on the difference between the pre- and post-pandemic worlds.[25]

[23]The sample of firms and time period used in Cooper and Haltiwanger (2006) differs from that of the BED. Nevertheless, we view the consistency of our model predictions with the estimated moments as an encouraging sign for our parametrization strategy.

[24]Note, however, that our model fails to replicate (by about a half) a fat enough tail of the firm size distribution; a common issue in firm dynamics models with log-normal productivity shocks. The Appendix provides an exercise in which we use the share of very large firms as an additional target showing that the results are not fundamentally affected.

[25]We do so because we are interested in structural shifts in remote work patterns *not* driven by lockdowns which we view as truly extraordinary events. While the latter may have sped up the transition towards remote work, a sustainable increase in work from home rates must ultimately be supported by underlying, fundamental, changes in the cost and efficiency of remote work arrangements.

Figure 3: Life-cycle profiles of size and exit rates: Data and model



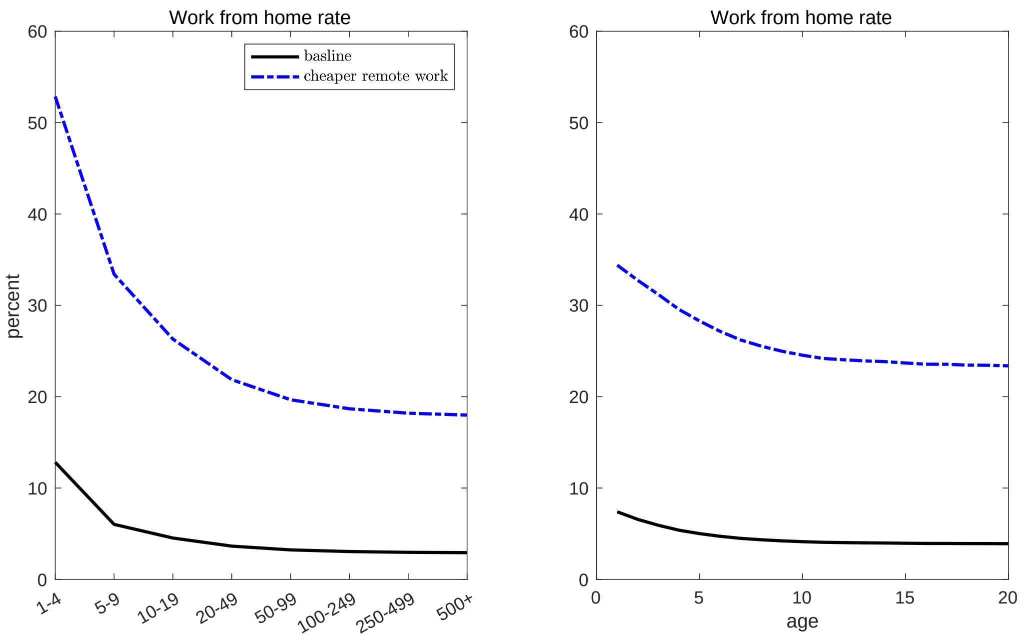
Note: The left panel shows average establishment size (employment) by age, while the right panel shows average exit rates by age for the model and the data. The latter is taken from the BED, averaged over the years 2003-2019.

To isolate the impact of changes in remote work conditions on the rest of the economy, we take our baseline economy (parameterized to the pre-pandemic period) as a starting point. Next, we adjust the parameters governing the efficiency and cost of remote work ($\widetilde{f}$ and $\widetilde{g}$) to mimic the increase in work from home observed after COVID-19, while keep all other features of the baseline model unchanged. We then quantitatively compare our baseline to the new equilibrium in the "post-pandemic" parameterization with cheaper and more efficient remote work practices. In the following paragraphs, we describe our approach in details.

The post-pandemic economy. There are two reasons that can induce firms to conduct more of their production remotely – either work from home becomes more efficient (a decline in $\widetilde{f}$), or it becomes cheaper (a rise in $\widetilde{g}$). Moreover, as explained in Section 2, the impact of these two sources of remote work changes is quantitatively different. Therefore, a key pre-requisite for our quantitative exercise is to determine the relative importance of efficiency and cost changes in driving up remote work rates in the post-pandemic period. Towards this end, we change $\widetilde{f}$ and $\widetilde{g}$ such that the resulting new general equilibrium features two important characteristics.

First, a work from home rate of 24%. This corresponds to the post-pandemic average computed using ATUS data. Second, we focus on the pattern of remote work changes across the firm size distribution. This is because larger firms are relatively less sensitive to changes in (fixed) costs as they represent a smaller fraction of their sales. Therefore, we target the relative increase in remote work rates of large firms (those with 100 and more employees) and all firms. Specifically, according to our linked ATUS-ASEC information,

Figure 4: Work from home: Firm size and age



Note: The figure shows average work from home rates by size (left panel) and age (right panel) for the "baseline" and for the new equilibrium with "more efficient and cheaper remote work."

remote work rates of large firms increased 1.06 times more compared to all businesses.

Using these two targets, our model suggests that – compared to the pre-pandemic average – $\widetilde{f}$ decreased by half while $\widetilde{g}$ increased about 4 times.[26] To put these changes into perspective, consider a typical firm with 4 percent of its employees working remotely. Holding the rate of remote work fixed, these changes imply that productivity losses would go from 0.02% to 0.01% and that cost savings would increase form 0.5% to 1.7%. Therefore, while these changes are large proportionally, their levels remain very modest.

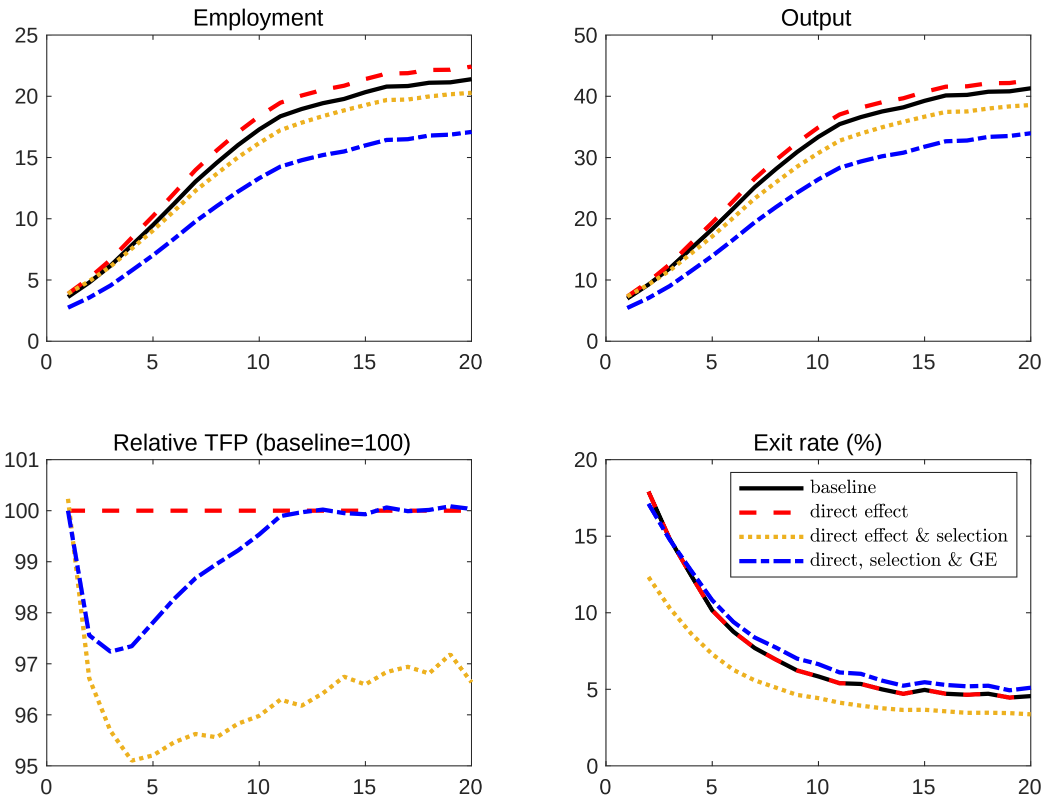
In what follows, we first describe how work from home rates changed across the firm size and age distributions. Next, we focus on their impact on business dynamism and use this evidence – together with BED data – to further validate our theory. Finally, we investigate how increased remote work rates affected the macroeconomy, including household welfare. Details of our computational strategy can be found in the Appendix.

5.1 Work from Home and Business Dynamism

In this subsection, we quantify the connection between work from home decisions and business dynamism.

[26]Davis et al. (2024) use a model of household decisions about remote work and also find that productivity of working from home increased substantially in the post-pandemic period.

Figure 5: Firm-level effects of cheaper and more efficient remote work



Note: The figure shows average firm-level employment (top left panel), output (top right panel), productivity (bottom left) and exit rates (bottom right panel) as a function of firm age. It does so for the "baseline" model, and for the case when remote work is cheaper and more efficient. The latter is shown in partial equilibrium, ignoring firm selection and GE effects ("direct effect"), in partial equilibrium with firm selection ("direct effect & selection") and in the new general equilibrium ("direct effect, selection & GE").

Work from home. Figure 4 shows average work from home rates as a function of firm size (left panel) and age (right panel). As explained in our parameterization section, larger firms tend to do less remote work. Since mature firms are on average larger, also older businesses tend to conduct less of their production remotely. The reason why the life-cycle profile is shallower than the size gradient of remote work is that our model features size heterogeneity even conditional on age. Therefore, average work from home rates of each age group mask an entire distribution of remote work rates related to firm size.

Firm size and selection. Next, Figure 5 displays how cheaper and more efficient work from home affects average firm-level employment (top left panel), output (top right panel), productivity (bottom left) and exit rates (bottom right panel). Each of these are plotted over firms' life-cycles.

In addition to our baseline specification (black solid line), we consider 3 different scenarios. First, the impact of cheaper work from home in partial equilibrium, ignoring both firm selection effects (entry and exit) and changes in equilibrium prices – this is shown by the "direct effects" line. Second, we consider the same, but allow for firm selection (changes in entry and exit), while keeping wages fixed – this is shown by the "direct effects & selection" line. Finally, we also plot the impact in general equilibrium (GE) allowing for a change in wages – this is shown in the "direct effects, selection & GE" line. The latter corresponds to the final general equilibrium of our post-pandemic economy.

Ignoring firm selection and general equilibrium effects, firms decide to expand production when remote work (and therefore production) becomes cheaper and more efficient (top panels). In doing so, note that firms reduce their capital-labor ratios as they take advantage of the relatively cheaper production factor (labor). By construction, average TFP and exit rates are unchanged when ignoring selection and GE effects (bottom panels). While the capital to labor ratio declines somewhat, the effect is quantitatively small even in partial equilibrium.

Cheaper production, however, raises profits and firm values. This, in turn, induces greater entry and reduces firm exit (bottom right panel) – as predicted by our stylized model in Section 2). Note that firm exit declines more for younger firms. This happens because younger firms are on average smaller and for such businesses the reduction in (fixed) costs related to work from home is relatively stronger. Therefore, some firms which could not afford to stay in business when remote work was costlier can now remain in operation. This pulls down average firm productivity (bottom left panel) and with it average firm size and output (top panels).

Finally, the greater mass of firms increases labor demand which raises equilibrium wages. This, in turn, makes it harder for all businesses to survive and exit rates increase across the board.[27] Because of weaker firm selection, average firm-level productivity is below the baseline level for younger firms. However, higher exit rates eventually lead to a catching up of average productivity to its baseline levels (bottom panels). Combining these effects, firms operate at smaller scales in the new general equilibrium (top panels).

Overall impact on entry and exit. The first column of Table 4 shows that both entry and exit (rates) increased considerably between the pre-pandemic period and 2022. As discussed in Decker and Haltiwanger (2023), this is surprising in the context of the last several decades of declining business dynamism and especially a reduction in the startup rate.

The second column of Table 4 shows that – according to our quantitative model – an incrased uptake of remote work arrangements can go a long way in explaining both

[27]Note that the lower capital to labor ratio also makes firms more fragile as lower capital levels are associated with higher exit.

Table 4: Model Results: Remote work and business entry and exit

	Overall Changes		Elasticities	
	Data	Model	$f(\omega)$	$g(\omega)$
Entry	28%	7%	0.03	0.98
Exit	15%	9%	0.06	0.97

Note: The table shows changes in entry and exit in the data (1st column) and the model (second column). The last two columns then report elasticities of the same variables when remote work increases are productivity-driven (third column, $f(\omega)$) and cost-driven (last column, $g(\omega)$).

these changes. In particular, one quarter of the entry rate increase and 60 percent of the exit rate rise can be explained by more attractive work from home arrangements alone. Therefore, while other factors – such as a fast-tracked spatial and sectoral restructuring of the economy or changes in entrepreneurs' preferences – likely play an important role (see Decker and Haltiwanger, 2023, for a discussion), in this paper we argue that cheaper and more efficient remote work options alone contributed to the observed entry and exit patterns.[28]

Relative strength. As a final step in this part of our analysis, we turn to one of our theoretical predictions. In particular, recall that Part d) of Proposition 2 states that the impact of changes in remote work rates on business entry and exit is stronger when they are cost-driven. We now test this in the generalized model.

Towards this end, we compute semi-elasticities of entry, exit and the respective firm sizes with respect to percentage point changes in work from home rates. The last two columns of Table 4 confirm that our theoretical predictions from the stylized model also carry over to the generalized framework. While qualitatively the same, productivity-driven changes in remote work have a much smaller effect quantitatively compared to cost-driven changes.

5.2 Work from Home and the Macroeconomy

In this subsection we quantify the macroeconomic impact of increases in work from home arrangements.

Total factor productivity. We begin by investigating changes of aggregate TFP, Z, in response to a greater adoption of remote work arrangments. In our framework, we can write aggregate output as

$$Y = Z(N^{\alpha}K^{1-\alpha})^{\theta},$$

[28] In the Appendix, we show that also the size of entering and exiting businesses seems to be associated with changes in the extent of remote work. Our model is consistent with these patterns as well.

Table 5: Impact of increased remote work: Changes in aggregates

	TFP (Z)			Output (Y)			Consumption (C)			Welfare ($\mathcal{W}$)	
Log-change		0.02			0.03			0.04		0.01	
Components	$\overline{z}$	$f(\overline{\omega})$	Δ	Z	N	K	Y	I	Costs	C	N
	-0.01	−0.02	0.05	0.02	0	0.01	0.05	-0.01	0	0.01	0

Note: The first row of the table shows log-changes in aggregate TFP (Z), output (Y), Consumption (C) and welfare ($\mathcal{W}$). The bottom rows then split the overall changes into the contributions of the various components.

where Y, N and K are, respectively, aggregate output, employment and capital. Aggregate TFP is then given by

$$Z = \overline{z}f(\overline{\omega}) \underbrace{\int_j \frac{1}{\Omega^\theta} \frac{z_j}{\overline{z}} \frac{f(\omega_j)}{f(\overline{\omega})} \left[\left(\frac{n_j}{\overline{n}}\right)^\alpha \left(\frac{k_j}{\overline{k}}\right)^{1-\alpha} \right]^\theta dj}_{\text{allocative efficiency, } \Delta}, \tag{23}$$

where bars indicate averages of a variable across the endogenous distribution of firms in the economy, e.g. $\overline{z} = \int z\mu(z,k)dzdk$. The above expression shows that aggregate TFP depends not only on average firm-level productivity, $\overline{z}$, but also on the distribution of business-level productivity, employment and capital – we refer to this term as allocative efficiency, Δ. Intuitively, with homogeneous firms, $\Delta = 1$ and TFP is identical to (homogeneous) firm-level productivity (including the endogenous component stemming from remote work choices), i.e. $Z = \overline{z}f(\overline{\omega})$. In contrast, with firm heterogeneity, the entire distributions of input factors matter for allocative efficiency.

The first three columns of Table 5 show how aggregate TFP changes between our baseline and the economy with cheaper and more efficient remote work. It reports the overall change (top row), but also the contributions of the individual factors $\overline{z}$, $\overline{f}$ and Δ (bottom two rows). First, in the new equilibrium, firms conduct more production remotely, which comes with efficiency losses ($f(\overline{\omega})$ falls by about 2 percent). In addition, more prevalent remote work changes the process of firm selection, tilting the firm distribution towards less productive firms ($\overline{z}$ declines by about 1 percent). However, firms also choose smaller scales of production on average – both because selection allows less productive (smaller) firms to survive, but also because of the general equilibrium increase in the cost of labor. With decreasing returns to scale, a larger mass of small production units improves allocative efficiency (an increase in Δ by almost 5 percent) and aggregate TFP rises.

Output and consumption. The next three columns of Table 5 investigate the change in aggregate output and its sources ($Y = Z(N^{1-\alpha}K^\alpha)^\theta$). In general equilibrium, aggregate output increases by about 3 percent. This is driven primarily by the rise in TFP discussed above and by capital deepening. The latter occurs because of the increased number of entering firms (despite them being smaller on average) and higher wages pushing firms to choose higher capital-labor ratios.

Next, columns 7-9 of Table 5 show the response of consumption and split its drivers into output, investment and costs ($C = Y - I - Costs$). The latter encompass capital adjustment costs, fixed operation costs and entry costs. Overall, consumption increases strongly, entirely driven by a rise in aggregate output. In contrast, higher investment (consistent with the increased aggregate capital stock) dampens consumption. On net, resources spent on costs do not change much as higher entry and capital adjustment costs are offset by lesser spending on overheads and non-wage labor costs due to increased remote work.

Welfare. Finally, the last two columns of Table 5 investigate the impact of increased remote work arrangements on household welfare ($\mathcal{W} = \log(C) - \upsilon N$). Note that our model is not particularly geared towards generating welfare benefits of work from home. First, remote work decisions are made at the firm level and households take them as given. Second, we do not explicitly model additional benefits of remote work such as a decline in commuting time (i.e. increased leisure and/or work hours), benefits for home-production (see e.g. Barrero et al., 2023, for a discussion).

Nevertheless, our model predicts that welfare increases by about 1 percent when moving towards more flexible remote work arrangements. This is entirely driven by the strong consumption increase. As discussed before, aggregate employment does not change much and, therefore, does not influence welfare quantitatively.

5.3 Discussion

This paper studies how expanded work from home practices can impact the macroeconomy using a new model with business dynamism and optimal remote work decisions of heterogeneous firms. In this section, we discuss a range of potential extensions and avenues for future research.

Fixed costs of starting remote work. In the baseline model, we assume that any business can employ some of its workforce remotely without incurring any setup costs. In reality, there may be costs associated with obtaining the necessary hard- or soft-ware for remote work, as well as putting in place processes for efficient use of remote work. The Appendix extends our baseline model to allow for such fixed setup costs.

The presence of fixed setup costs gives rise to an interesting additional "extensive margin" channel. In particular, changes in the conditions of remote work would impact the share of firms engaging in work from home arrangements. Quantitatively evaluating the relative strength of the intensive vs extensive margins would be interesting. However, disciplining these margins would require information on the share of firms engaging in remote work. To the best of our knowledge, such data is currently lacking.

Richer heterogeneity. While our model exhibits a mix of ex-post (persistent shocks) and ex-ante heterogeneity (initial values), we abstract from *permanent* differences across firms. Existing papers have highlighted that such heterogeneity may be important in understanding business dynamism and macroeconomic movements (see e.g. Sterk et al., 2021). Similarly, there is evidence that particular occupations and worker "types" are more likely to tele-work than others (see e.g. Barrero et al., 2023).

We believe that incorporating and linking such richer firm and worker heterogeneity is a potentially fruitful avenue for future research. A key prerequisite, however, is high quality data on work from home arrangements *at the firm level*. Currently, the vast majority of available information on remote work is at the worker level (see e.g. Barrero et al., 2023) or at the job add level (see e.g. Hansen et al., 2023).

Other factors. Our model predicts that about 30 percent of the entry rate spike during and in the aftermath of the COVID pandemic can be explained by increased remote work arrangements. We are well aware of several other factors that likely also contributed to the entry rate increase – e.g. the Payment Protection Program, or geographic restructuring of production in urban areas (see e.g. Decker and Haltiwanger, 2023). Future research may concentrate on the interaction of remote work with these other factors to better understand the margins to which business entry is most sensitive.

6 Conclusion

In this paper, we study the macroeconomic impact of the large increase in work from home arrangements observed since the COVID-19 pandemic. We do so by proposing a new macroeconomic model of business dynamism in which firms can optimally choose to conduct part of their production remotely. We show analytically how such a framework generates a link between observed work from home rates and firm entry and exit. In addition, we confirm the model's predictions in the data and extend our baseline framework along several dimensions to quantify the macroeconomic impact of work from home.

We find that the observed rise in remote work rates can account for about one third of the observed firm entry rate increase. It also leads to a shift towards smaller businesses, improves allocative efficiency, raises output and welfare. To the best of our knowledge, we are the first to analyze how work from home practices impact the macroeconomy.

Our paper also opens the door to several additional aspects which would be interesting to study in future research. For example, how does (permanent) firm heterogeneity interact with the possibility of remote work or how does it reinforce or dampen the impact of other factors influencing firm entry? We believe that more work – including the collection of economy-wide information on remote practices at the firm-level – is needed to better understand the aggregate impact of the increasing trend of remote work.

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A Stylized Model: Additional Details and Proofs

This Appendix provides additional details on the stylized model of Section 2, as well as all the theoretical proofs.

A.1 Model Details

In this Appendix, we provide the remaining details to our stylized model. In particular, we describe the household problem, aggregation and formally define the equilibrium.

Household Problem. A representative household owns all businesses in the economy and optimally chooses aggregate consumption, C, and labor, N, to maximize:

$$\ln C - \upsilon N,$$

subject to a budget constraint:

$$C = WN + \Pi,$$

where $\upsilon > 0$ is the disutility of labor supply, the aggregate price is normalized, and Π is the real aggregate profits.

Aggregation. The following conditions describe goods and labor market clearing, where $\mu(z)$ is the stationary distribution of the incumbent firms (whose mass is normalized):

$$Y = \int y_t \mu(z) dz,$$

$$N = \int n_t \mu(z) dz.$$

Finally, the aggregate resource constraint is given by

$$Y = C + M\kappa_e + \int g(\omega_t)(\kappa_n n_t + \kappa_o)\mu(z) dz,$$

where aggregate output is used for consumption and all paid costs, including entry costs, non-wage labor costs and overhead costs.

Equilibrium. A stationary equilibrium consists of (i) a value function $v(z)$ and policy functions $n(z)$, $\omega(z)$, $\widetilde{z}$ and (ii) a wage rate $W \geq 0$, mass of entrants $M \geq 0$, and a measure of incumbents $\mu(z)$, such that:

- $v(z)$, $n(z)$, $\omega(z)$ and $\widetilde{z}$ solve the incumbent's problem (2) and satisfy the exit threshold (3),

- the free entry condition (5) is satisfied with equality if $M > 0$,
- the labor market clears (24),
- and the distribution of firms satisfies (4).

A.2 Proofs

In what follows, we provide all the proofs to our propositions in the main text.

Proof of Proposition 1. Differentiating $\pi(z)$ w.r.t. ω and n gives the FOCs:

$$f'(\omega)zn^{\alpha} - g'(\omega)(\kappa_n n + \kappa_o) = 0 \quad (24)$$
$$f(\omega)z\alpha n^{\alpha-1} - W - g(\omega)\kappa_n = 0 \quad (25)$$

a) if $\kappa_o = 0$, then combining the two FOCs and rearranging gives ω^* such that:

$$\frac{f'(\omega^*)}{f(\omega^*)}\frac{g(\omega^*)}{g'(\omega^*)} = \alpha\frac{g(\omega^*)\kappa_n}{W + g(\omega^*)\kappa_n},$$

b) if $\kappa_o > 0$, differentiating Equations (24) and (25) w.r.t. z gives:

$$[f''(\omega^*)zn^{*\alpha} - g''(\omega^*)(\kappa_n n^* + \kappa_o)]\frac{\partial\omega^*}{\partial z} + [f'(\omega^*)z\alpha n^{*\alpha-1} - g'(\omega^*)\kappa_n]\frac{\partial n^*}{\partial z} + f'(\omega^*)n^{*\alpha} = 0$$

$$[f'(\omega^*)z\alpha n^{*\alpha-1} - g'(\omega^*)\kappa_n]\frac{\partial\omega^*}{\partial z} + f(\omega^*)z\alpha(\alpha-1)n^{*\alpha-2}\frac{\partial n^*}{\partial z} + f(\omega^*)\alpha n^{*\alpha-1} = 0$$

Combining the two equations gives:

$$\{(\frac{f''g' - g''f'}{g'^3})f\alpha(\alpha-1) - [\frac{f'}{g'}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}}]^2\}\frac{\partial\omega^*}{\partial z} = \frac{f\alpha\kappa_o}{g'z^2n^{*\alpha}}$$

Since $\kappa_o > 0$ and $g' < 0$, $\frac{\partial\omega^*}{\partial z} < 0$ if and only if:

$$(\frac{f''g' - g''f'}{g'^3})f\alpha(\alpha-1) > [\frac{f'}{g'}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}}]^2 \quad (26)$$

We can derive the necessary condition from (26):

$$\frac{f''}{f'} > \frac{g''}{g'}$$

Proof of Proposition 2. Assume two coefficients $\widetilde{f}$ and $\widetilde{g}$ that govern the velocity of productivity loss and cost saving. Specifically, we have: $\frac{\partial f(\widetilde{f},\omega)}{\partial \widetilde{f}} < 0$, $\frac{\partial g(\widetilde{g},\omega)}{\partial \widetilde{g}} < 0$, $\frac{\partial^2 f(\widetilde{f},\omega)}{\partial \widetilde{f}\partial\omega} > 0$ and $\frac{\partial^2 g(\widetilde{g},\omega)}{\partial \widetilde{g}\partial\omega} > 0$ when $\omega \in (0, 1]$.

For simplicity, we denote $\frac{\partial f(\widetilde{f},\omega)}{\partial \widetilde{f}}$ as f_1, $\frac{\partial f(\widetilde{f},\omega)}{\partial \omega}$ as f_2, $\frac{\partial^2 f(\widetilde{f},\omega)}{\partial \widetilde{f}\partial \omega}$ as f_{12}, and $\frac{\partial^2 f(\widetilde{f},\omega)}{\partial \omega^2}$ as f_{22}. Similar for $g(\widetilde{g},\omega)$. We can rewrite Equation (24) and (25) as:

$$f_2(\widetilde{f},\omega^*)zn^{*\alpha} - g_2(\widetilde{g},\omega^*)(\kappa_n n^* + \kappa_o) = 0 \quad (27)$$
$$f(\widetilde{f},\omega^*)z\alpha n^{*\alpha-1} - W - g(\widetilde{g},\omega^*)\kappa_n = 0 \quad (28)$$

Proof of $\frac{\partial \omega^*}{\partial \widetilde{f}} < 0$. Differentiating Equations (27) and (28) w.r.t. $\widetilde{f}$ gives:

$$f_{12}zn^{*\alpha} + (f_2 z\alpha n^{*\alpha-1} - g_2\kappa_n)\frac{\partial n^*}{\partial \widetilde{f}} + [f_{22}zn^{*\alpha} - g_{22}(\kappa_n n^* + \kappa_o)]\frac{\partial \omega^*}{\partial \widetilde{f}} = 0$$
$$f_1 z\alpha n^{*\alpha-1} + fz\alpha(\alpha-1)n^{*\alpha-2}\frac{\partial n^*}{\partial \widetilde{f}} + (f_2 z\alpha n^{*\alpha-1} - g_2\kappa_n)\frac{\partial \omega^*}{\partial \widetilde{f}} = 0$$

Combining the two equations and rearranging gives:

$$[\frac{f_{22}g_2 - f_2 g_{22}}{g_2^3}f\alpha(\alpha-1) - (\frac{f_2}{g_2}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}})^2]\frac{\partial \omega^*}{\partial \widetilde{f}} = \frac{f_1 f_2 - f_{12}f}{g_2^2}\alpha(\alpha-1) + \frac{f_1}{g_2}\frac{\alpha\kappa_o}{zn^{*\alpha}}$$

Thus $\frac{\partial \omega^*}{\partial \widetilde{f}} < 0$ iff

$$[\frac{f_{22}g_2 - f_2 g_{22}}{g_2^3}f\alpha(\alpha-1) - (\frac{f_2}{g_2}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}})^2][\frac{f_1 f_2 - f_{12}f}{g_2^2}\alpha(\alpha-1) + \frac{f_1}{g_2}\frac{\alpha\kappa_o}{zn^{*\alpha}}] < 0$$

Combining with Proposition 1, we have $\frac{\partial \omega^*}{\partial \widetilde{f}} < 0$ and $\frac{\partial \omega^*}{\partial z} < 0$ iff:

$$\frac{f_{22}g_2 - f_2 g_{22}}{g_2^3}f\alpha(\alpha-1) - (\frac{f_2}{g_2}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}})^2 > 0$$
$$\frac{f_1 f_2 - f_{12}f}{g_2^2}\alpha(\alpha-1) + \frac{f_1}{g_2}\frac{\alpha\kappa_o}{zn^{*\alpha}} < 0 \quad (29)$$

We thus obtain the further necessary condition from (29):

$$\frac{f_1 f_2 - f_{12}f}{g_2^2}\alpha(\alpha-1) < 0 \iff f_1 f_2 > f_{12}f$$

Proof of $\frac{\partial \omega^*}{\partial \widetilde{g}} > 0$. Differentiating Equations (27) and (28) w.r.t. $\widetilde{g}$ gives:

$$[f_{22}zn^{*\alpha} - g_{22}(\kappa_n n^* + \kappa_o)]\frac{\partial \omega^*}{\partial \widetilde{g}} + (f_2 z\alpha n^{*\alpha-1} - g_2\kappa_n)\frac{\partial n^*}{\partial \widetilde{g}} - g_{21}(\kappa_n n^* + \kappa_o) = 0$$
$$(f_2 z\alpha n^{*\alpha-1} - g_2\kappa_n)\frac{\partial \omega^*}{\partial \widetilde{g}} + fz\alpha(\alpha-1)n^{*\alpha-2}\frac{\partial n^*}{\partial \widetilde{g}} - g_1\kappa_n = 0$$

Combining the two equations and rearranging gives:

$$[\frac{f_{22}g_2 - f_2 g_{22}}{g_2^3} f\alpha(\alpha-1) - (\frac{f_2}{g_2}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}})^2]\frac{\partial\omega^*}{\partial\widetilde{g}} = \frac{g_{21}f_2 f}{g_2^3}\alpha(\alpha-1) - \frac{g_1\kappa_n}{g_2 zn^{*\alpha-1}}(\frac{\alpha f_2}{g_2} - \frac{\kappa_n}{zn^{*\alpha-1}})$$

Thus $\frac{\partial\omega^*}{\partial\widetilde{g}} > 0$ iff:

$$[\frac{f_{22}g_2 - f_2 g_{22}}{g_2^3} f\alpha(\alpha-1) - (\frac{f_2}{g_2}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}})^2][\frac{g_{21}f_2 f}{g_2^3}\alpha(\alpha-1) - \frac{g_1\kappa_n}{g_2 zn^{*\alpha-1}}(\frac{\alpha f_2}{g_2} - \frac{\kappa_n}{zn^{*\alpha-1}})] > 0$$

Combining with Proposition 1, we have $\frac{\partial\omega^*}{\partial\widetilde{g}} > 0$ and $\frac{\partial\omega^*}{\partial z} < 0$ iff:

$$\frac{f_{22}g_2 - f_2 g_{22}}{g_2^3} f\alpha(\alpha-1) - (\frac{f_2}{g_2}(\alpha-1) + \frac{\kappa_o}{zn^{*\alpha}})^2 > 0$$

$$\frac{g_{21}f_2 f}{g_2^3}\alpha(\alpha-1) - \frac{g_1\kappa_n}{g_2 zn^{*\alpha-1}}(\frac{\alpha f_2}{g_2}\frac{\kappa_n}{zn^{*\alpha-1}}) > 0 \tag{30}$$

We thus obtain the further necessary condition from (30), using $\frac{\kappa_n}{zn^{*\alpha-1}} = \frac{\alpha f\kappa_n}{W+g\kappa_n}$ and $\frac{f\kappa_n}{W+g\kappa_n} < \frac{f}{g}$:

$$\frac{f}{f_2} < \frac{1-\alpha}{\alpha}\frac{g_{21}}{g_1}\frac{g^2}{g_2^2} + \frac{g}{g_2}$$

which further implies

$$\frac{f_2}{f} > \frac{g_2}{g}$$

Note that if $\kappa_n = 0$, $\frac{\partial\omega^*}{\partial\widetilde{g}} < 0$ unambiguously. So that $\kappa_n > 0$ is also a necessary condition to get $\frac{\partial\omega^*}{\partial\widetilde{g}} > 0$.

Proof of $\frac{\partial\pi^*}{\partial\widetilde{f}} < 0$ and $\frac{d\widetilde{z}}{d\widetilde{f}} > 0$. By the envelope theorem, we have:

$$\frac{\partial\pi^*}{\partial\widetilde{f}} = f_1(\widetilde{f},\omega^*)zn^{*\alpha} < 0 \tag{31}$$

Since $\pi^*(\widetilde{z}) \equiv 0$, fixing $\widetilde{g}$ and using the envelope theorem, we have:

$$0 \equiv \frac{d\pi^*(\widetilde{z}(\widetilde{f}))}{d\widetilde{f}} = \frac{\partial\pi^*}{\partial\widetilde{f}}|_{z=\widetilde{z}} + \frac{\partial\pi^*}{\partial\widetilde{z}}\frac{d\widetilde{z}}{d\widetilde{f}} \tag{32}$$

which implies $\frac{d\widetilde{z}}{d\widetilde{f}} > 0$, as $\frac{\partial\pi^*}{\partial\widetilde{f}} < 0$ and $\frac{\partial\pi^*}{\partial z} = f(\widetilde{f},\omega^*)n^* > 0$ by the envelope theorem.

Proof of $\frac{\partial\pi^*}{\partial\widetilde{g}} > 0$ and $\frac{d\widetilde{z}}{d\widetilde{g}} < 0$. By the envelope theorem, we have:

$$\frac{\partial\pi^*}{\partial\widetilde{g}} = -g_1(\widetilde{g},\omega^*)(\kappa_n n^* + \kappa_o) > 0 \tag{33}$$

Since $\pi^*(\widetilde{z}) \equiv 0$, fixing $\widetilde{f}$ and using the envelope theorem, we have:

$$0 \equiv \frac{d\pi^*(\widetilde{z}(\widetilde{g}))}{d\widetilde{g}} = \frac{\partial \pi^*}{\partial \widetilde{g}}|_{z=\widetilde{z}} + \frac{\partial \pi^*}{\partial \widetilde{z}} \frac{d\widetilde{z}}{d\widetilde{g}} \tag{34}$$

which implies $\frac{d\widetilde{z}}{d\widetilde{g}} < 0$, as $\frac{\partial \pi^*}{\partial \widetilde{g}} > 0$ and $\frac{\partial \pi^*}{\partial z} > 0$.

Proof of $|\frac{\partial \pi^*}{\partial \widetilde{g}}| > |\frac{\partial \pi^*}{\partial \widetilde{f}}|$ and $|\frac{\partial \widetilde{z}}{\partial \widetilde{g}}| > |\frac{\partial \widetilde{z}}{\partial \widetilde{f}}|$. Using the previous results, we can prove the following equivalence relations:

$$\begin{aligned}
\left|\frac{\partial \pi^*}{\partial \widetilde{g}}\right| &> \left|\frac{\partial \pi^*}{\partial \widetilde{f}}\right| \\
\overset{(31),(33)}{\Longleftrightarrow} -g_1(\widetilde{g}, \omega^*)(\kappa_n n^* + \kappa_o) &> -f_1(\widetilde{f}, \omega^*) z n^{*\alpha} \\
\overset{(27)}{\Longleftrightarrow} g_1(\widetilde{g}, \omega^*) &< f_1(\widetilde{f}, \omega^*) \frac{g_2(\widetilde{g}, \omega^*)}{f_2(\widetilde{f}, \omega^*)} \\
\Longleftrightarrow \frac{g_1}{g_2} &> \frac{f_1}{f_2}
\end{aligned} \tag{35}$$

where (35) is the necessary and sufficient condition to obtain $|\frac{\partial \pi^*}{\partial \widetilde{g}}| > |\frac{\partial \pi^*}{\partial \widetilde{f}}|$.

Again we use the previous results:

$$\begin{aligned}
\left|\frac{\partial \widetilde{z}}{\partial \widetilde{g}}\right| &> \left|\frac{\partial \widetilde{z}}{\partial \widetilde{f}}\right| \\
\overset{(32),(34)}{\Longleftrightarrow} \frac{\frac{\partial \pi}{\partial \widetilde{g}}|_{z=\widetilde{z}}}{\frac{\partial \pi}{\partial z}|_{z=\widetilde{z}}} &> -\frac{\frac{\partial \pi}{\partial \widetilde{f}}|_{z=\widetilde{z}}}{\frac{\partial \pi}{\partial z}|_{z=\widetilde{z}}} \\
\Longleftrightarrow \left.\frac{\partial \pi}{\partial \widetilde{g}}\right|_{z=\widetilde{z}} &> -\left.\frac{\partial \pi}{\partial \widetilde{f}}\right|_{z=\widetilde{z}} \\
\Longleftrightarrow \left.\frac{g_1}{g_2}\right|_{z=\widetilde{z}} &> \left.\frac{f_1}{f_2}\right|_{z=\widetilde{z}}
\end{aligned}$$

which is satisfied automatically from (35).

Therefore, we show that the impact of $\widetilde{g}$ on profits and cutoff productivity is more significant than that of $\widetilde{f}$ iff (35) holds.

Consider a small change in $\widetilde{g}$ and a small change in $\widetilde{f}$ such that they result in the same new $\omega^*(> \omega_0^*)$, given the productivity level z. This is to say:

$$\frac{\partial \omega^*}{\partial \widetilde{g}} \Delta \widetilde{g} = \frac{\partial \omega^*}{\partial \widetilde{f}} \Delta \widetilde{f}$$

where $\Delta\widetilde{f} < 0$ and $\Delta\widetilde{g} > 0$. Then we can prove the following equivalence condition:

$$\begin{aligned} \pi(\widetilde{f} + \Delta\widetilde{f}, \widetilde{g}) - \pi(\widetilde{f}, \widetilde{g}) &< \pi(\widetilde{f}, \widetilde{g} + \Delta\widetilde{g}) - \pi(\widetilde{f}, \widetilde{g}) \\ \iff f_1(\widetilde{f}, \omega^*) z n^{*\alpha} \Delta\widetilde{f} &< -g_1(\widetilde{g}, \omega^*)(\kappa_n n^* + \kappa_o)\Delta\widetilde{g} \\ \overset{(27)}{\iff} f_1 \Delta\widetilde{f} &< -g_1 \frac{f_2}{g_2} \Delta\widetilde{g} \\ \iff -f_1 \frac{\partial\omega^*}{\partial\widetilde{g}} &< g_1 \frac{f_2}{g_2} \frac{\partial\omega^*}{\partial\widetilde{f}} \\ \iff \frac{f_1 g_1}{f_2 g_2} &< -\frac{\partial\omega^*}{\partial\widetilde{f}} \Big/ \frac{\partial\omega^*}{\partial\widetilde{g}} \end{aligned}$$

B Empirical Analysis: Additional Exercises and Robustness

In this Appendix, we consider various robustness checks to our empirical analysis of Section 3. We also provide a comparison between the BED and BDS data.

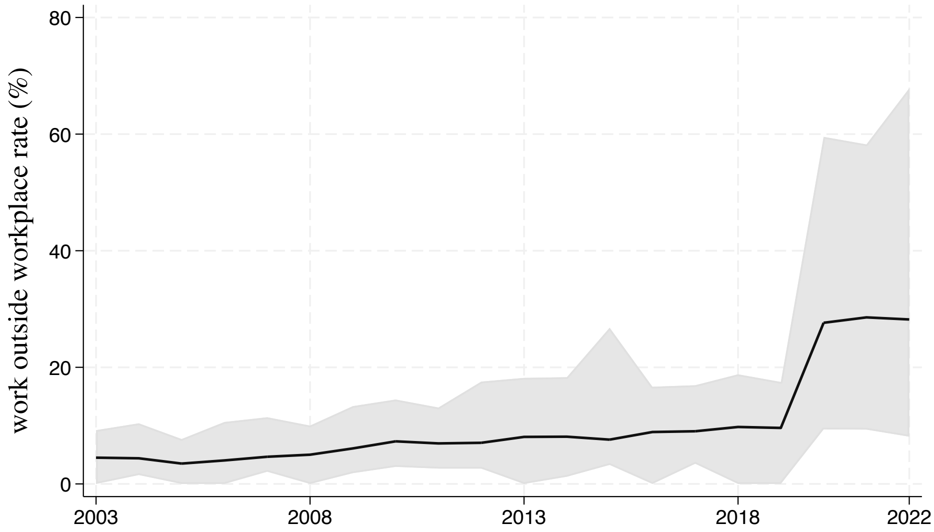
B.1 Robustness: Working Outside the Workplace

As discussed in the main text, we use work-outside-workplace rate to replace work from home rate in the empirical analysis. Table 6 and Figure 6 show the evolution of working-outside-workplace rate from 2003 to 2019. Figure 7 shows the changes across industries. The construction of work-outside-workplace is similar to that of work from home rate, defined in equation (6), in that we count a day as work outside workplace if the individual spent in total at least 6 hours working at home or other places except their workplace.

Table 6: Evolution of Working Outside Workplace

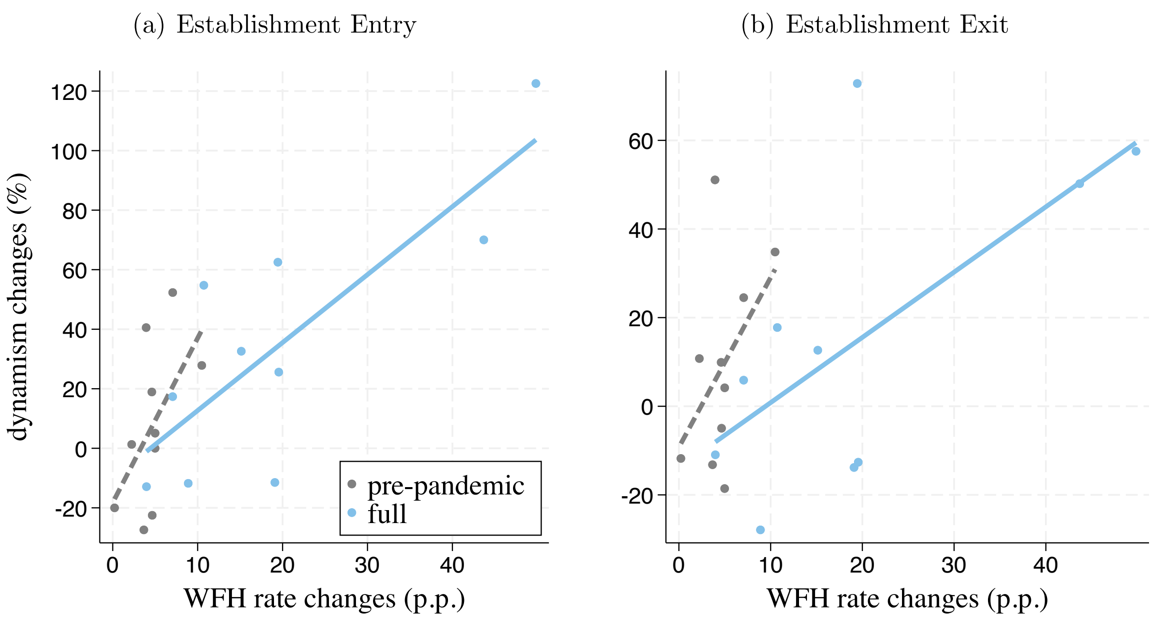
Year	Rate (%)	
	work-from-home	work-outside-workplace
2003	1.8	4.5
2004	2.7	4.4
2005	1.9	3.5
2006	1.9	4.0
2007	2.8	4.7
2008	3.4	5.0
2009	4.4	6.1
2010	4.3	7.3
2011	3.9	6.9
2012	4.1	7.1
2013	4.3	8.1
2014	5.6	8.1
2015	5.7	7.6
2016	4.7	8.9
2017	5.9	9.0
2018	5.9	9.8
2019	6.7	9.6
2020	24.0	27.6
2021	26.0	28.6
2022	23.9	28.2

Figure 6: Work outside workplace rate: Changes over time



Note: The figure shows work outside workplace rates over time for the aggregate economy (solid black line) and the range of values across industries (shaded area).

Figure 7: Work Outside Workplace and Business Dynamism: Changes across Industries



B.2 Robustness: 2-digit Sectors

We use annual establishment age data at 2-digit level from BED, where establishment entry is reflected in the number of establishments of age less than one year. We dropped "Agriculture, forestry, fishing, and hunting", "Mining, quarrying, and oil and gas extraction" and "Management of companies and enterprises", due to limited observations in ATUS. Besides, "Finance and insurance" sector is excluded, consistent with the previous analysis at the super sector level. Figure 8 shows the linkage between work from home rates and business entry. Table 7 shows the results of fixed effect regression, where the average WFH rate is constructed with two lags, i.e., average of the current and the previous two years' WFH rate.

Figure 8: Work from Home and Business Entry: Changes across 2-digit Industries

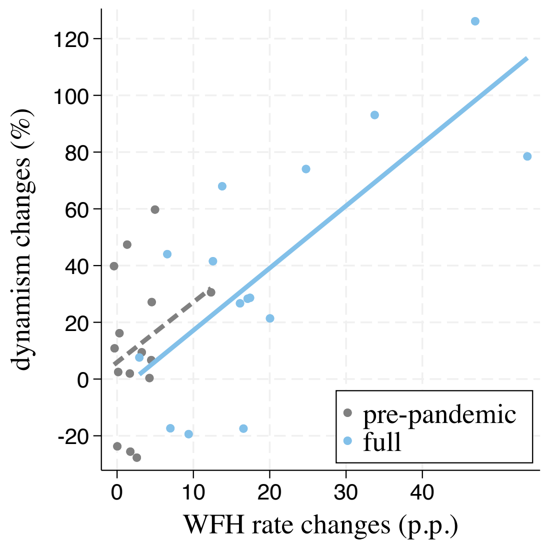


Table 7: Working from home and business entry ($L = 2$)

	Pre-pandemic	Full sample
Average WFH rate, β	1.118***	2.079***
	(0.415)	(0.199)
Industry & time f.e.	✓	✓
Controls	✓	✓
R-squared	0.524	0.718
# observations	225	270

B.3 Robustness: Openings and Closings

As discussed in the main text, BED establishment openings include both births and re-openings, while establishment closings include both deaths and temporary closings. Here we use quarterly establishment openings and closings at the super sector level, consistent with the analysis in the main text. Table 8 reports the results. In Table 9, we further investigate the 2-digit scenario.

Table 8: Working from home, establishment openings and closings (super sectors)

	Pre-pandemic		Full sample	
	Openings	Closings	Openings	Closings
Average WFH rate, β	0.997***	0.854***	0.951***	0.682***
	(0.176)	(0.177)	(0.0990)	(0.0984)
Industry & time f.e.	✓	✓	✓	✓
Controls	✓	✓	✓	✓
R-squared	0.440	0.466	0.701	0.651
# observations	590	590	710	710

Table 9: Working from home, establishment openings and closings (2-digit sectors)

	Pre-pandemic		Full sample	
	Openings	Closings	Openings	Closings
Average WFH rate, β	0.428***	0.333***	1.093***	0.809***
	(0.149)	(0.153)	(0.0721)	(0.0737)
Industry & time f.e.	✓	✓	✓	✓
Controls	✓	✓	✓	✓
R-squared	0.348	0.350	0.689	0.621
# observations	756	756	923	923

B.4 Robustness: Different Lag Lengths

In the main text, we use the current quarter and the last year's WFH rates to construct the regressor. To further validate the lagged impacts of working from home on business entry and exit, we consider $L = 2$ and $L = 6$ in constructing the average WFH rate. Table 10 and 11 report the results.

B.5 Comparison between BED and BDS Data

Although we use BED data at the establishment level for calibration, we provide a comparison between BED and BDS data here. From Figure 9, life-cycle profiles of size and exit rates of BED establishments are close to those of BDS firms.

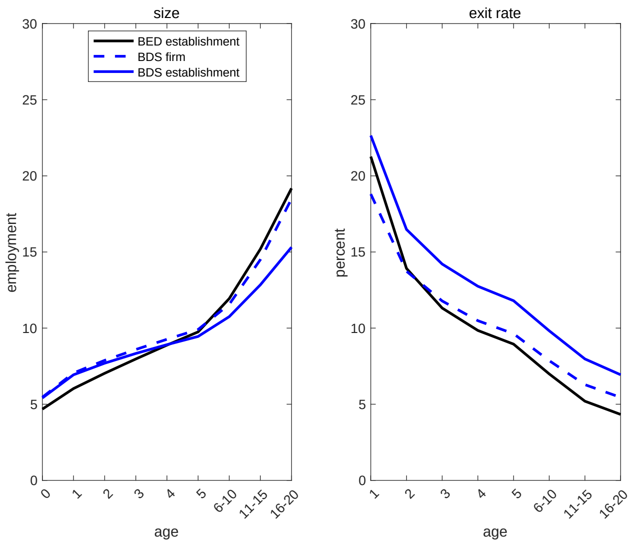
Table 10: Working from home and business dynamism ($L = 2$)

	Pre-pandemic		Full sample	
	Entry	Exit	Entry	Exit
Average WFH rate, β	0.756***	0.772***	0.991***	0.576***
	(0.165)	(0.181)	(0.105)	(0.108)
Industry & time f.e.	✓	✓	✓	✓
Controls	✓	✓	✓	✓
R-squared	0.472	0.381	0.692	0.516
# observations	590	590	710	690

Table 11: Working from home and business dynamism ($L = 6$)

	Pre-pandemic		Full sample	
	Entry	Exit	Entry	Exit
Average WFH rate, β	1.606***	1.425***	1.532***	1.223***
	(0.257)	(0.289)	(0.128)	(0.134)
Industry & time f.e.	✓	✓	✓	✓
Controls	✓	✓	✓	✓
R-squared	0.522	0.446	0.722	0.544
# observations	550	550	670	650

Figure 9: Life-cycle profiles of size and exit rates: BED and BDS



Note: The left panel shows average establishment size from BED and firm/establishment size from BDS by age, while the right panel shows average exit rates by age.

C Generalized Model: Additional Details and Results

This Appendix provides a formal definition of equilibrium in the generalized model and sketches an extension of our model for fixed costs of setting up remote work.

C.1 Equilibrium Definition in Generalized Model

A stationary equilibrium consists of (i) a value function $v(z,k)$ a policy functions $n(z,k)$, $\omega(z,k)$, $\widetilde{z}(k)$, $x(z,k)$ and (ii) a wage rate $W \geq 0$, a mass of entrants $M \geq 0$, and a measure of incumbents $\overline{\mu}(z,k)$ (with $\mu(z,k)$ denoting the probability distribution), such that:

- $v(z,k)$, $n(z,k)$, $\omega(z,k)$, $\widetilde{z}(k)$, $x(z,k)$ solve the incumbent's problem (11);
- the free entry condition (36) is satisfied
- the labor market clears (18)
- the distribution of firms satisfies

$$\overline{\mu}(z',k') = \int\int \Phi(z',k'|z,k)d\overline{\mu}(z,k) + M\mathbb{1}[k' = x(z',0)]H(z'),$$

  where

$$\Phi(z',k'|z,k) = F(z'|z)\mathbb{1}[k' = x(z,k) + (1-\delta)k(z,k)]\mathbb{1}[\widetilde{z}(k)],$$

  and where $\mathbb{1}[\widetilde{z}(k)]$ is an indicator function equal to 1 when firms decide to remain in operation, $F(z'|z)$ is the transition function for productivity shocks described in (9) and, therefore, where $\Phi(z',k'|z,k)$ denotes the transition from (z,k) to (z',k').

C.2 Model with Fixed Setup Cost

In this Appendix, we extend our generalized model to include fixed costs of setting up remote work.

Firm Values and Optimal Decisions. Based with the model in the main text, we further consider a setup cost for working from home, κ_ω.

In particular, the beginning-of-period value of a businesses in operation which has not yet decided to conduct production remotely is given by

$$v(z_t,k_t) = \max_{n_t,x_t}\left\{\pi_t + \beta(1-\delta)\int \max\left[\mathbb{E}_t v^x(z_{t+1},k_{t+1}), \mathbb{E}_t v^c(z_{t+1},k_{t+1}) - \widetilde{\kappa}_o\right] dH_\kappa(\widetilde{\kappa}_o)\right\},$$

where $v^c(z,k)$ is the continuation values, given by

$$v^c(z_t,k_t) = \max\left[v(z_t,k_t), v^\omega(z_t,k_t) - \kappa_\omega\right].$$

The above shows that the value of continuation depends on whether or not firms decide to begin remote work. Choosing to do so, requires firms to pay κ_ω. Then, the beginning-of-period value of a business which can conduct part of its production remotely is given by

$$v^\omega(z_t,k_t) = \max_{n_t,x_t,\omega_t}\left\{\pi_t + \beta(1-\delta)\int \max\left[\mathbb{E}_t v^x(z_{t+1},k_{t+1}), \mathbb{E}_t v^\omega(z_{t+1},k_{t+1}) - \widetilde{\kappa}_o\right] dH_\kappa(\widetilde{\kappa}_o)\right\},$$

Firm Entry. We assume that startups enter with no workers, but they do have the choice of immediately choosing to conduct some remote work.

Assuming free entry, the following condition implicitly pins down the mass of entrants, M:

$$\kappa_e = \int_z \max\left[v(z,0), v^\omega(z,0) - \kappa_\omega\right] dH_z(z).$$

Aggregation. Finally, the aggregate resource constraint is given by

$$Y = C + M\kappa_e + \int\int \left[\zeta(x_t,k_t) + g(\omega_t)(\kappa_n n_t + \mu_\kappa) + \widetilde{\kappa}_o\right] d\mu(z,k) + T_t\kappa_\omega,$$

where the costs of setting up remote work are included, and T_t is the mass of firms deciding to start conducting a fraction of their production remotely.