DISCUSSION PAPER SERIES

DP18092

MORE WORKING FROM HOME - AGGREGATE AND DISTRIBUTIONAL IMPACTS OF SHIFTS IN RESIDENTIAL LOCATION

David Miles and James Sefton

MACROECONOMICS AND GROWTH

ISSN 0265-8003

MORE WORKING FROM HOME - AGGREGATE AND DISTRIBUTIONAL IMPACTS OF SHIFTS IN RESIDENTIAL LOCATION

David Miles and James Sefton

Discussion Paper DP18092
Published 20 April 2023
Submitted 09 March 2023

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

MORE WORKING FROM HOME - AGGREGATE AND DISTRIBUTIONAL IMPACTS OF SHIFTS IN RESIDENTIAL LOCATION

Abstract

We analyse how greater ability for some to work from home might affect relative and absolute house prices and generate impacts on welfare for different households with unequal options about flexible work. We find that a plausible calibration for the scale of greater ability of many people to work from home creates substantial long run impacts on house values, population density and welfare. The resulting pattern of house prices and location rarely generates any losers though the benefits are far from equally distributed. The implications for residential location and density are often not what one might expect.

JEL Classification: R21, N90, R30, R31

Keywords: Working from home

David Miles - d.miles@imperial.ac.uk
CEPR and Imperial College London and CEPR

James Sefton - j.sefton@imperial.ac.uk
Imperial College, London

Acknowledgements
We thank participants at seminars at the London Business School, Imperial College and Oxford University for comments and suggestions.

More working from home –aggregate and distributional impacts of shifts in residential location

David Miles*and James Sefton†

March 8, 2023

Abstract

We analyse how greater ability for some to work from home might affect relative and absolute house prices and generate impacts on welfare for different households with unequal options about flexible work. We find that a plausible calibration for the scale of greater ability of many people to work from home creates substantial long run impacts on house values, population density and welfare. The resulting pattern of house prices and location rarely generates any losers though the benefits are far from equally distributed. The implications for residential location and density are often not what one might expect.

JEL classification: R21,N90,R30,R31.

Keywords: Working from home, Commuting, House Prices.

*Corresponding Author: CEPR and Imperial College Business School, Imperial College London, London, SW7 2AZ; e-mail d.miles@imperial.ac.uk

†Imperial College Business School, Imperial College London, South Kensington Campus, London SW7 2AZ; e-mail j.sefton@imperial.ac.uk.

1 Introduction

Restrictions introduced to help stop the spread of the Covid-19 virus revealed that many businesses were able to continue far more effectively than had seemed likely with most of their employees working from home. As a result it now seems very likely that for many employees – though certainly not all – working from home for part of the week is an option that will be more readily available than was the case just a few years ago. Early evidence from the UK and the US (Adams-Prassl et al. (2022); Barrero et al. (2021); Davis et al. (2021); Taneja et al. (2021); Gupta et al. (2022)) suggests many employers will allow most of their employees to work 1 or 2 days a week from home after the virus is behind is. This has the potential to have a large effect on where people chose to live. Early evidence from the US suggests such effects could be significant (Delventhal & Parkhomenko (2020); Davis et al. (2021); Chen et al. (2023)). In this paper we aim to assess the scale of impacts upon house values, on density of population at different locations, on residential building, and on welfare of different types of households from a sudden and unanticipated increase in the ability of some (but not all) households to work from home.

Jerbashian & Vilalta-Bufí (2022) provide evidence from across European countries, and across sectors, showing differences in the scale of working from home. They find a very marked increase in 2020 when Covid hit. But they also show that this was very different across occupations, suggesting significant distributional impacts of more working from home. That is an issue we analyse in some detail. Barrero et al. (2021) present evidence from an even broader range of countries. They too find a very substantial - though unequally distributed - expansion in work from home opportunities after 2020. They explain this sharp rise thus:

"First, the pandemic compelled a mass social experiment in WFH. Second, that experimentation generated a tremendous flow of new information about WFH and greatly shifted perceptions about its practicality and effectiveness. The simultaneity of experimentation across suppliers, producers, customers and commercial networks yielded experience and information that was hard to acquire before the pandemic."

These developments could change the relative (and the average) price of housing within countries. In urban centres within rich economies where a very high proportion of jobs have been prices may fall relative to in locations which have been seen as too far from work places to be consistent with a daily commute.

The scale of these effects is hard to judge from trends in house values, in commuting patterns and in residential construction because the period since a major shift in opportunities to work from home happened is very short relative to the likely horizon over which adjustments in housing markets and in travel patterns will take place. Transactions costs in moving house are substantial; switches in use of buildings from one use to another is costly and is likely to be very gradual; transport infrastructure is slow to change. Most important, it is only now that Covid restrictions are lifted in most countries are employers beginning to decide on what work from home options to offer employees. For all these reasons it is likely to be hard to discern the longer run implications of greater scope for some people to work from home by looking at the evidence from housing markets in the period since Covid arrived in early 2020.

In this paper we use a model designed to uncover the relation between distance from urban centres, travel to work costs and the pattern of residential prices and density to assess what the long run implications of a sudden, but permanent, shift in the ability to work from home might be. We use a model of the evolution of relative house prices and residential density developed by Miles and Sefton (2021). In that model the time-varying pattern of costs and benefits of living at different distances from urban centres −for which the need to commute is central −was the key factor in driving cross-sectional differences in house values and population densities within an economy. That model is well suited to assess the impacts of a sudden shift in those costs; greater ability of some agents to work from home with its reduction in commuting is just such a shift.

The effects of such a shift is very unlikely to be uniform and will have different impacts on people in different types of job (see early evidence from Barrero et al. (2021)). It is likely that the scope to work from home will tend to be greater in higher paid jobs; many low paid sectors of the economy (hospitality, agriculture, nursing, catering, cleaning) have very little scope to allow home working. Men and women with a University degree can do an above average share of their tasks from home (Adams-Prassl et al. (2020)). These differences may be becoming greater as employers invest in allowing those already able to work from home to do so more effectively.

The distributional impacts of greater working from home are therefore potentially significant. One way this could arise is that shifts in home prices could differ by the value of houses generating changes in the distribution of wealth. Declines in the relative price of housing in (currently expensive) urban centres have complicated effects – they decrease the future cost of housing for those who have limited ability to move away from cities because there is little scope to work from home. But at the same time they can drive down relative home values for those who have already bought houses and have no compensation in the form of the benefit of working from home.

Because of the huge significance of housing wealth and of housing costs there is the potential for more working from home to have large aggregate and distributional impacts. But there is little evidence yet on the likely scale of effects. This paper analyses the plausible scale and timing of such effects. We will build on recent work in the analysis of how travel to work costs impact the location and price of housing adapting a model that seems well suited to the estimation of the effects of a rise in the ability to work from home.

We will pay attention to the potential for there to be a strong correlation between greater ability to work from home and current incomes. Such a strong correlation could mean that the benefits of more working from home go disproportionately to the better off; it could even mean the less well-off are on average worse off. But that is by no means inevitable even if the scope to work from home is very limited for the great majority of those on lower wages while it is substantial for nearly all the currently higher paid. That is because the overall impact on household welfare of some people working more from home comes through several different channels. Those able to work more from home benefit directly from that option and the scope it brings to live in places previously infeasible. But the housing market responses have further impacts because they result in shifts in the price of existing houses and in future housing costs (which are distinct things). Clearly such shifts affect all households – including those who cannot work from home. As with all housing market shifts they also affect different generations in distinct ways. We aim to assess the nature of such effects.

There are four specific questions which we use the calibrated model of residential location choice to address:

1. What is the likely scale of the long run shifts in the relative prices of housing and in population density at varying distances from urban centres?

2. What is the absolute and relative scale of the changes in welfare between those who have greater opportunities to work from home and those that do not?

3. What are the conditions under which those who do not have greater ability of work from home gain or lose from the greater ability of others with higher average incomes to do so?

4. Are the short run impacts upon welfare and upon housing markets likely to be different (potentially in sign as well as magnitude) than long run effects?

The answers to these questions have significant policy implications. The distributional impacts (within and between generations) of work from home opportunities that will be very uneven across employment sectors are potentially significant. If they are adverse on the less well-off (which is not obvious) they may prompt policies that offset them – for example, help with technologies that enable more working from home (subsidies on broadband/investment in areas of the public sector where work from home opportunities are currently limited); investment in types of transport infrastructure.

There is scope that more working home brings to increase housing affordability in general and not just for those most able to work flexibly. It can also change housing policy, most obviously in the planning area which effects where houses can be built.

The financial implications of significant changes in relative home values are potentially large. In some areas home values may rise significantly and in other home values may fall. If these changes come over a short period then for some mortgage debt may rise or fall substantially relative to home values; rents may change even faster than home values. The gains and losses such changes generate will not be random but vary systematically by area generating pockets of winners and losers and downward and upward momentum to local economies. Mortgage lenders and investors in residential and commercial properties will feel effects.

We find substantial impacts on the values of existing houses at different locations when work from home opportunities suddenly rise. The distributional impacts are substantial: not surprisingly those most able to benefit from increased opportunities gain signifcantly relative to those whose options about on travelling to work have not changed. But we do not find that there are widespread losers - even amongst those who cannot work from home. We find that the overall implications for residential location and density are, in some respects, counter-intuitive, though the economic forces at work are clear enough when we consider how work form home opportunities vary with incomes.

1.1 Plan of the paper

In section 2 we describe the model that we use to investigate these questions. Calibration of the model based on the evidence of greater ability for some to work from home is described in Section 3. Simulation results are shown in Section 4. Section 5 draws conclusions.

2 The Model[1]

2.1 The physical environment

We assume a circular economy in which people live at locations of varying distance $l \in [0, l_{\max}]$ from the centre ($l = 0$) potentially up to the periphery of the economy (at $l_{\max}$). The physical area of the economy is $\pi l_{\max}^2$ which is the aggregate quantity of land. The central business district (CBD) is located at $l = 0$. There are advantages to living close to the centre, the most significant of which we assume to be commuting costs. Though we recognise that in actual economies there may be many more than one central business location, we adopt the assumption of a monocentric economy for analytical tractability. Key results do not depend crucially on there only being one urban centre. We expand on this below.

The monocentric assumption allows us to describe the distance to work from anywhere in the economy by the distance l to the centre, implying that the urban area where all housing is distance l from the centre is an annulus. This means it is easy to integrate the populated area of the economy. It also implies that the rate of expansion in the urban area will be linear in its radius. A more involved geography with many urban centres would make things more complicated once cities begin to overlap. However, the core ideas in this paper will all go through.

We assume a simple cost of distance function. We think of this as reflecting a rising cost of living further from the central district where employers are assumed to be located. At distance l from the CBD, $1 + \lambda_t l$ of consumption good must be purchased to consume 1 unit of the good. We think of $\lambda_t l$ as the tax on location with λ_t as the impact at time t

[1] This section draws heavily on Miles and Sefton (2021) which presents the main features of the model in more detail, provides proofs and describes solution methods.

of distance on that tax rate[2]. There is no reason to think that $\lambda_t l$ is constant over time - it reflects technology (most obliviously travel technology) which has improved dramatically over the last couple of centuries. We model a change in the ability to work from home as a reduction (sudden and unexpected) in λ_t , though it is one that may only apply to a subset of households.

2.2 The households

The agents in the model are households each of which is a member of an infinitely lived dynasty. There is a continuum of dynasties on the unit interval. Though the number of dynasties remains constant over time, the number of people in the current household of each dynasty grows at rate m which is therefore also the rate of population growth. If we normalize total population to be 1 at time $t = 0$, then at time t the population, $n(t)$, is equal to e^{mt}. Labour is supplied inelastically by each household in proportion to dynastic size at each period, and so the labour force, L_t, grows at rate m too.

The are 2 type of households, labelled 'office workers' and 'home workers'. The 'office workers' have limited ability to work from home while 'home workers' are those for whom opportunities to work from home will become substantially higher. (The labels are not ideal since most of those who have the least ability to work from home are not actually office workers - fire fighters, the police, nurses, cleaners, drivers are in fact those with virtually no scope to work from home). There is an equal number of each type of households. Household types differ by their labour productivity or human capital endowment, H^j where $j \in \{ow, hw\}$ (referring to whether they are a office or home worker respectively) and their cost of travel λ_t^j where $j \in \{ow, hw\}$. We normalise their respective human capital endowments so that $\sum_j 0.5H^i = 1$ implying the effective labour supply is equal to the total population size, L_t. To capture the notion that higher paid workers generally have greater capacity to work more time at home (Adams-Prassl et al. (2020)), we assume $H^{hw} \geqslant H^{ow}$ and $\lambda_t^{hw} \leqslant \lambda_t^{ow}$.

Utility comes from the consumption of goods, denoted C, and of housing services, S. Preferences over these goods at a given time t is described by a constant elasticity of substitution (CES) utility function

$$Q_{it} = \left[aC_{it}^{1-1/\rho} + (1-a)S_{it}^{1-1/\rho} \right]^{1/(1-1/\rho)} \tag{1}$$

where $\rho \in (0, 1)$ is the elasticity of substitution between housing and consumption goods and a is a share parameter. We refer to the quantity Q as the composite consumption good or simply the composite good. The indices $i \in [0, 1]$ and $t \in [0, \infty)$ index the quantity to dynasty i at time t. Dynastic welfare is the discounted power function of the composite

[2] There are many aspects of the cost of location and several interpretations of $\lambda_t l$. The most obvious is travel costs - you need to spend time and money on getting nearer to the centre where you may work. It is also consistent with Krugman's model of commuting costs, where all dynasties have a fixed supply of labor but lose a proportion of this supply in commuting to the CBD for work.

good

$$\int_0^\infty \frac{1}{1-\gamma} Q_{it}^{(1-\gamma)} e^{-\theta t} dt \tag{2}$$

where γ reflects the degree of inter-temporal substitutability and θ is the discount factor. We use the dynasty[3] as our decision making unit throughout - which is equivalent to assuming that the members of a dynasty alive at each time maximsie the dynastic welfare function.

People can choose where to live at each point in time. There are no costs to moving from one location to another so that people, given a chosen expenditure, pick the location that maximises the consumption of the composite good at each point in time. Up to a scalar factor on income (which reflects permanent differences in labour productivity) all people share the same economic environment and have the same preferences. If there was one location preferred by people of a given wage (labour productivity) then all people with that labour productivity would prefer this same location. Therefore a necessary condition for an equilibrium in the housing market is that the maximum utility that can be derived from each location for a given labour productivty type is the same. In this housing market, the centripetal force attracting dynasties towards the CBD is the lower commuting costs. The offsetting centrifugal force is that housing costs (that is rental rates) become more expensive closer to the CBD. As there are no other forces affecting the choice of location these two forces need to be exactly offsetting at each location in equilibrium.

For this condition to hold, the rental price of housing services for each labour productivity type at each location l must satisfy

$$p_{lt}^{S,j} = \left(\left(p_{0t}^{S,j} \right)^{1-\rho} - \left(\frac{a}{1-a} \right)^{\rho} \left(\left(1 + \lambda_t^j l \right)^{1-\rho} - 1 \right) \right)^{1/(1-\rho)} \tag{3}$$

where $p_{0t}^{S,j}$ is the rental price that type is willing to pay at the CBD. When office workers face a higher cost of travel, $\lambda_t^{ow} > \lambda_t^{hw}$, their willingness to pay for housing services near the CBD will be higher, $p_{0t}^{S,ow} < p_{0t}^{S,hw}$, and so the price of housing serices will be set by office workers. However, as the distance from the CBD increases, there will be a switching point or kink when the willingness to pay of home workers becomes greater than the office workers. At this point the rental price is set by home workers. We therefore observe that once $\lambda_t^{ow} > \lambda_t^{hw}$ there is segregation in the housing market with what is known in the spatial geography literature as the bid-price function for housing set as

$$p_{lt}^{S} = \max \left(p_{lt}^{S,hw}, p_{lt}^{S,ow} \right).$$

[3]We could equally have done the analysis in per capita terms. Assume that the flow of dynastic utility at time t is the sum of utilities of identical dynastic members then alive - whose number is proportional to $n(t)$. Because the utility function is constant returns to scale (CRS) and population growth is constant the welfare function in (2) can be re-written in per capita terms but with an adjusted discount rate $\widetilde{\theta} = \theta + \gamma m$. Thus the dynastic welfare function (2) is equivalent to a welfare function that is the sum over members of the dynasty of their individual utilities, but with a shifted discount factor.

The dynastic inter-temporal budget constraint at time $t = 0$ for each household type can then be written

$$W_0^j + \int_0^\infty e^{-\int_0^t r_\tau d\tau} w_t^j e^{mt} dt = \int_0^\infty e^{-\int_0^t r_\tau d\tau} p_{0t}^j Q_t dt \tag{4}$$

where the second term is the dynastic human capital: the total present discounted value of future labour income from the supply of one unit of labour by each member of the dynasty type at their wage w_t^j. As the the ratio of wages between higher and lower paid workers is fixed by their relative labour productivities, if their is no difference in their costs of travel then their relative housing and wealth will also be in the same ratio. Once we consider recent greater opportunities for work from home things will change because those opportunities seem to have been greater (and likely will remain greater) for the relatively higher paid. We will consider the implications of sudden, but permanent, greater opportunties to work from home (that is a lower value of λ refelcting less need to commute) that comes only to the higher paid workers, who we label "the work from home".

2.3 Production

The production side of the economy consists of 2 sectors; a goods production sector and a housing production sector. The goods production sector uses Cobb-Douglas technology, F, to manufacture the single good. This good can be consumed, C, or invested in productive capital, I_t^K, or in residential buildings, I_t^B. We assume a constant rate of labour augmenting technical progress, g. Thus production in the goods sector is

$$C_t + I_t^K + I_t^B = F\left(K_t, L_t e^{gt}\right) = A K_t^\alpha \left(L_t e^{gt}\right)^{1-\alpha} \tag{5}$$

where α is the capital share of output. All the variables in equation (5) are aggregates; we use the notation that aggregate quantities are indexed by t only. We assume that improvements in building structures proceeds at the same rate as general productivity improvements in goods production. The stock of capital, K, and residential buildings, B, evolve over time as

$$\dot{K}_t = I_t^K - \delta^K K_t \tag{6}$$

$$\dot{B}_t = I_t^B - \delta^B B_t \tag{7}$$

where δ^K and δ^B are the respective constant depreciation rates of productive capital and residential buildings.

Housing at location l at time t is provided by combining structures, B_{lt}, and land, R_{lt}. The same CES technology is used at all locations, though the mix of buildings and land varies by location. The production of housings services[4] S_{lt} at location l is

$$S_{lt} = H(B_{lt}, R_{lt}) = A_s \left[bB_{lt}^{1-1/\varepsilon} + (1-b)R_{lt}^{1-1/\varepsilon} \right]^{1/(1-1/\varepsilon)}. \tag{8}$$

where ε is the elasticity of substitution between land and structure and b is a share parameter. A_s is a constant of proportionality between the flow of services and the stock of housing. As the equilibrium solution is invariant to the product of rental prices, p_{lt}^S, and this flow constant - that is, for example, a doubling of the flow constant leads to a halving of rental prices in equilibrium - we set this constant to 1 in the simulations.

2.4 Allocation in the Housing Market

In equilibrium, residential buildings earn a real rate of return, r_t, whatever their location. This condition sets the mix of residential structures to land at each location l. The real return to structures at location l is their marginal product minus depreciation

$$r_t = \left(p_{lt}^S \frac{\partial H(B_{lt}, R_{lt})}{\partial B_{lt}} - \delta_B \right) = p_{lt}^S b A_s \left(b + (1-b) \left(\frac{R_{lt}}{B_{lt}} \right)^{1-1/\varepsilon} \right)^{1/\varepsilon/(1-1/\varepsilon)} - \delta_B \tag{9}$$

This condition (9) implies that the stock of residential structures and the associated flow of housing services per unit area of land at location l is

$$B_{lt} = \left(\frac{1}{(1-b)} \left(\frac{p_{lt}^S b A_S}{r_t + \delta_B} \right)^{1-\varepsilon} - \frac{b}{(1-b)} \right)^{\varepsilon/(1-\varepsilon)} R_{lt} \tag{10}$$

$$S_{lt} = A_S \left(\frac{1}{(1-b)} - \frac{b}{(1-b)} \left(\frac{r + \delta_B}{p_{lt}^S b A_S} \right)^{1-\varepsilon} \right)^{\varepsilon/(1-\varepsilon)} R_{lt} \tag{11}$$

As rental rates, p_{lt}^S, fall away from the centre, equation (10) implies that the ratio of land to structures rises.

The edge of the urban sprawl will be defined by **either** the condition that the marginal product of structures must be greater than or equal to the interest rate, r_t, as the ratio of structures to land tends towards 0 **or** that rental prices, p_{lt}^S, must be greater than or equal to 0. If $\varepsilon < 1$(and there is a great deal of empirical evidence to suggest it is) then the first of these constraints is tighter whereas for $\varepsilon \geq 1$ only the latter bites[5]. Hence for $\varepsilon < 1$ the edge of the urban extent of the economy at time t, denoted by $l_{t,\text{Edge}}$, is set by the home

[4] By S_{lt} we refer to the supply of housing services derived from the buildings B_{lt} and land R_{lt} at location l. In contrast S_{it} refers to the use of housing services by dynasty i. We shall relate the two shortly in order to calculate the amount of land occupied by dynasty i.

[5] This follows as the former constraint is equivalent to requiring that $p_{lt}^S \geq \left(\frac{(r_t + \delta_B)}{A_s b^{1/(1-1/\varepsilon)}} \right)$ when $\varepsilon < 1$ whereas the latter is the simpler condition that $p_{lt}^S \geq 0$.

workers (unless the costs of travel are the same in which case there is no difference)

$$l_{t,\text{Edge}} = \min\left(l_{\max}, \frac{1}{\lambda_t^{hw}}\left(\left(1+\left(\left(p_{0t}^{hw}\right)^{1-\rho} - \left(\frac{(r_t+\delta_B)}{A_s b^{1/(1-1/\varepsilon)}}\right)^{1-\rho}\right)\left(\frac{(1-a)}{a}\right)^{\rho}\right)^{1/(1-\rho)} - 1\right)\right) \tag{12}$$

whereas for $\varepsilon \geq 1$ the edge of the urban extent is the slightly simpler expression

$$l_{t,\text{Edge}} = \min\left(l_{\max}, \frac{1}{\lambda_t^{hw}}\left(\left(1+\left(p_{0t}^{hw}\right)^{1-\rho}\left(\frac{(1-a)}{a}\right)^{\rho}\right)^{1/(1-\rho)} - 1\right)\right). \tag{13}$$

To complete the description of the housing sector, we consider the price at time t of land at a distance l from the centre, denoted p_{lt}^R. At all locations the return to land must be equal to the real interest rate, r_t. This return to land is the sum of its marginal product, $p_{l\tau}^S \frac{\partial H(B_{l\tau}, R_{l\tau})}{\partial R_{l\tau}}$, plus any capital gains implying

$$r_t p_{lt}^R = p_{l\tau} \frac{\partial H(B_{l\tau}, R_{l\tau})}{\partial R_{l\tau}} + \dot{p}_{lt}^R. \tag{14}$$

Integrating this relationship forward subject to the standard transversality condition (that the growth in land prices is less than the interest rate in the long run) gives the price of land as the discounted value of all its future land rents, that is

$$p_{lt}^R = \int_t^\infty e^{-\int_t^\tau r_v dv} p_{l\tau}^S \frac{\partial H(B_{l\tau}, R_{l\tau})}{\partial R_{l\tau}} d\tau \tag{15}$$

We can also derive an alternative expression for rental prices (often referred to as the user cost of housing) as the value weighted average of the gross return to structures plus land rental rates. Given the production of housing services is constant returns to scale the value of the output of housing services is equal to the sum of the gross marginal products times the input good. If we substitute out for the marginal products using equations (9) and (14) and rearrange then

$$p_{lt}^S = (r_t+\delta_B)\left(\frac{B_{lt}}{S_{lt}}\right) + \left(r_t - \frac{\dot{p}_{lt}^R}{p_{lt}^R}\right)\left(\frac{p_{lt}^R R_{lt}}{S_{lt}}\right). \tag{16}$$

Thus the return, r_t, on a 'house', whose value is $B_{lt} + p_{lt}^R R_{lt}$ at location l , is equal to rents, $p_{lt}^S S_{lt}$, minus depreciation on the buildings plus capital appreciation on the land.

2.5 Equilibrium

For an equilibrium we need a path for prices r_t, w_t and p_{0t}^S such that the goods, labour and housing markets clear. Rental prices, p_{lt}^S, at all locations are described in terms of the price at the CBD, p_{0t}^S, in equation (3). The price of land, p_{lt}^R, is also driven off rental prices, p_{0t}^S, and is the present discounted value of future land rents as given in equation

(15). Both dynasty types have an initial endowment of wealth equal to the initial land value LW_0^j (equation (15)) plus capital stock, $K_0^j + B_0^j$. That is $W_0^j = LW_0^j + K_0^j + B_0^j$. Since wage/productivity differences are assumed permanent the better paid households have initial endowments that are scaled up versions of those of the less well paid.

2.6 Balanced Growth Path

Miles and Sefton show that in this model there can be a balanced growth path (BGP) if a particular condition holds. Effective labour supply grows at the sum of the rate of productivity plus population growth, $g + m$. If the travel tax, λ_t, falls at half this rate, $(g + m)/2$, then, as long as the urban expansion does not approach the edge of the country, $l_{t,\text{Edge}} \ll l_{\max}$, the economy will tend toward a balanced growth path (BGP) where all economic aggregate quantities grow at the rate $g + m$ and the average prices of land and housing are constant. Our model, therefore, admits a balanced growth path, even though one of the factors is land and is in fixed supply.

The conditions for a balanced growth path are exactly the same if there are multiple urban centres each of which spreads out in expanding circle as the economy grows at a rate of $(g+m)/2$. (But the conditions for balanced growth would change if cities start to overlap); then there is a slightly different condition for balanced growth. If, for example, there were two main centres of activity within a country then the rate of expansion of the area around each centre on a balanced path would grow at twice the rate of travel improvements until those two areas overlapped. From then on the pace of expansion of the feasible area would - for a given speed of travel improvement - initially slow down. Thus the condition for a balanced growth path would be that the pace of travel improvements would need to rise for a period once the cities overlap to offset that. Ultimately the cities would once again increasingly resemble a single circular city so the balanced growth condition would revert towards its original level.

Circular development for non-overlapping cities is, nonetheless, restrictive. But it has an economic logic - circular development is efficient because it maximises the expansion of the feasible commuting zone for a given increase in travel speeds.

3 Calibration

We outline how we set key parameters. For some parameters we can take guidance from values that are implied by steady state growth paths. As we argued in Miles and Sefton (2021), the evolution of productivity, population and transport costs mean that for many developed economies the condition for steady state growth (λ falls at the rate $(g + m)/2$) may have approximately held for roughly the 100 years 1860-1960 and so key aggregate ratios for that period help in calibration.

We begin by calibrating the key parameter that we vary to reflect a sudden change in work from home opportunities - that is λ , which reflects the time cost of commuting.

$\boldsymbol{\lambda}$: In our main set of simulations we assume that until a sudden rise in opportunities to work from home the cost of distance per mile ($\boldsymbol{\lambda}$) has been the same for all households and is proportional to the inverse of the average speed of commuting. Miles and Sefton (2021) present evidence that rises in speeds were most rapid between the mid nineteenth century and the second world war; they then slowed until the 1970s and - at best - have been static since then. We therefore look at two scenarios; firstly when λ for both household types falls by 1.5% and so the economy is on a balanced growth path before the shock; secondly λ for both household types falls by only 0.75% a year and so the economy experiences steadily rising house prices. In both scenarios, we then examine what happens when there is sudden option for the higher paid home workers to work 2 days a week from home, a fall of 40% in their travel costs λ^{hw}

m : We set population growth at 1.0% a year.

g : We set g at 0.02 based on historical long run growth in productivity in many developed economies of around 2%.

$\boldsymbol{\delta}_K$: On a steady state growth path $\delta_K = (I^k/K) - (m+g)$. Using US data on the average ratio of non residential capital investment to the non residential capital stock since 1929, and using the values of $m+g$ as above, implies a depreciation rate of just above 6%. For the US Davis & Heathcote (2005) use a quarterly value for depreciation of business capital of 0.0136 (annual of around 5.4%). Kiyotaki et al. (2011) use 10%. We set depreciation at 7% a year.

$\boldsymbol{\delta}_B$: As with nonresidential capital, on a steady state growth path the depreciation of residential capital is given by $\delta_B = (I^B/B) - (m+g)$ Using US data on the average ratio of residential capital investment to the residential capital stock since 1929, and using the values of $m+g$ as above, implies a depreciation rate of only around 1.25% a year. This seems slightly lower than estimates based on the difference between gross and net US residential investment which gives a a figure near 2%. We set depreciation on residential structures at 2% a year.

$\boldsymbol{\gamma}$: There is much evidence that the degree of inter-temporal substitutability is less than 1. Hall (1988) estimated it was close to zero. Subsequent work suggests a significantly higher value, but still less than unity (see Ogaki & Reinhart (1998) and Vissing-Jørgensen (2002)). We set the intertemporal elasticity to 0.67 which implies $\gamma = 1.5$.

$\boldsymbol{\theta}$: On a steady state path $r = \theta + \gamma(m+g)$. Given the values used for γ, m, g we can use this relation to gauge a plausible value of θ conditional on an assumed value for the steady state rate of return. In our model all assets (land, nonresidential capital, structures, housing) generate the same return. In practice assets obviously do not generate the same average returns. A recent paper (Jordà et al. 2019) provides data on the real returns on a range of assets (including equities, bonds and housing) over the period 1870-2015 for 16 advanced economies. Returns on equities and housing look similar and average about 7%

a year - though they are a little lower pre-1950. Bonds generate a lower real return which averages about 2.5% over the whole sample. The equally weighted average of the three asset classes is close to 6%. A figure of 6-7% seems reasonable for the past average return on real assets. If we assume the steady state real rate of return is around 6.5% then based on the values for γ, g, m above (respectively 1.5, 0.02 and 0.01) the implied value of θ is around 0.02. That is the value we take for the rate of time preference.

$\boldsymbol{\alpha}$: We set α (the share parameter in the production function) to the typical share of capital in private domestic value added in developed economies in recent years. This figure is around 0.3, Rognlie (2016).

$\boldsymbol{\varepsilon}$: Muth (1971) estimates the elasticity of substitution between land and structures in producing housing at 0.5; later work finds a slightly higher level, but well under 1. Thorsnes (1997) puts estimates in the range 0.5 to 1. Ahlfeldt & McMillen (2014) suggest it might be a bit under 1. Kiyotaki et al. (2011) constrain it to 1 in their calibrated model. But the weight of evidence is for a number under 1. For our base case we use a value of 0.5. We also consider higher values.

$\boldsymbol{\rho}$: There are many estimates from the empirical literature on housing of the elasticity of substitution between housing and consumption in utility. Ermisch et al. (1996) summarised that literature and put the absolute value at between 0.5 and 0.8; Rognlie (2016) uses a range of 0.4 to 0.8. Kiyotaki et al. (2011) constrain it to 1 in their calibrated model. Van Nieuwerburgh & Weill (2010) use 0.5 for the price elasticity of demand for housing, basing their choice on micro studies. Albouy et al. (2014) and Albouy et al. (2016) find strong US evidence for a value of 2/3. For our base case we use a value of 0.6; we also consider higher values.

H : We assume that the home workers have a labour producticity endowment that is 50% greater than the office workers, $H^{hw} = 1.2$ and $H^{ow} = 0.8$.

We solve the model under the assumption that agents are rational and forward-looking. Since there are no stochastic elements this means we are looking for a perfect foresight path that satisfies all the equilibrium conditions including the transversality conditions expressed over an infinite horizon. In practise, we need to solve the model over a finite horizon subject to a terminal condition (see Miles and Sefton (2021) for details).

4 Results

We present simulations of the sudden, unexpected and permanent rise in the ability of the group of higher wage workers to work from home. We consider a substantial decline in travel costs associated with a 2 day a week decrease in the need to travel to work for the better paid which is a fall in their cost of distance parameter of 40%. We assume this option becomes known at a date one year before it is actually realised. (This could be considered the time taken to be able to move to a location which reflects the changed opportunties and to arrange changes to travel and domestic arrangements; it also reflects the lag between companies announcing a change in work arrangements and implementing it). We consider two economic environments in which this shock occurs - when the economy was on a balanced growth path (so that the decline in the cost of distance due to faster travel times is one half of the growth of GDP and where land with no residential development is available) and another where we are off the balanced growth path with travel improvements already below the rate of growth of GDP. In the first, the sum of productivity growth and population growth is 3% and travel was improving at 1.5% a year; in the second travel improvements were lower at only 0.75% a year.

In these simulations we constrain gross investment (in residential capital and in capital used in production) to be non-negative. For residential buildings this constraint holds at all locations - which means we do not allow houses to be picked up and moved from one location to another as a sudden rise in work from home opportunities means part of the stock of residential buildings is in "the wrong place". Such adjustments can only happen by higher gross investment in locations that suddenly become more attractive while depreciation (and zero gross investment) happens in places where homes have become less attractive. This generates a transition period and one on which at those locations where houses have become less attractive the value of the structure (and so the house price) falls below the level if such structures could be moved to where they are more valued. This means that while the constraint binds the equality of the value of structures across locations does not hold.

4.1 Balanced growth:

Figure 1 shows the impact on land prices of the sudden improvement in work from home opportunities. We measure distance from the centre on the horizontal axis; initially the edge of residential development is at distance 1 from the centre. There is a very substantial decline in land values (and so the cost of creating new homes and the price of existing ones) at the majority of locations at which households were living. Note that the value of structures built on land at different locations is unchanged only at locations where the constraint on no negative residential investment does not bind - for such locations value of capital (including structures) is determined by the marginal cost of creating new capital. Figure 1 shows that land price declines are very different at different locations and beyond some distance from the centre the declines become much smaller. Declines of 20% to 25% in land values where density had been high are seen. The decline in land value is not at its greatest closest to the urban centre. The fall in land values there is just under 20% but is over 25% further out. What happens here is those that cannot work from home move much closer to the centre when land values fall and this cushions the fall in price there. There is an area further from the centre which becomes even less attractive than being at the centre. This is because the greater work from home opportunities make places substantially further from the centre more attractive for those who can take advantage of it, while for those with no opportunities to work from home it is more attractive to move

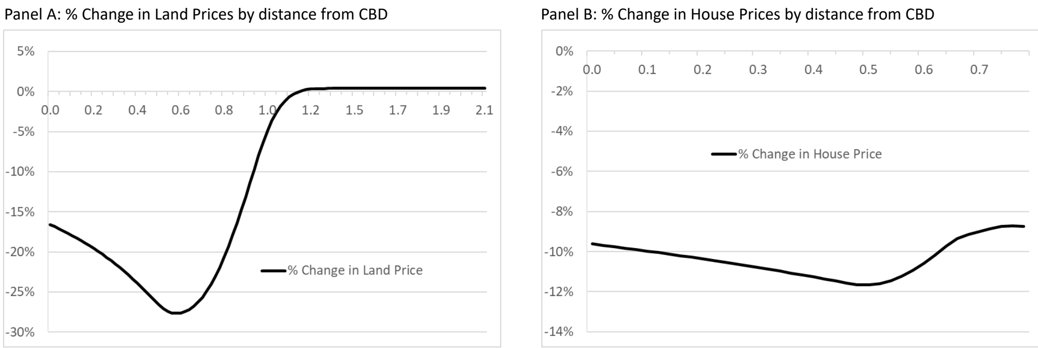

Figure 1: % Change in Land Values by distance from CBD at time $t = 0$. The distance is scaled so that at $t = 0$ the $l_{Edge} = 1$. The changes are a result of a shock that lowers the cost of working from home relative to the balance growth path

into the newly cheaper areas much closer to the centre. Places within every-day commuting distance from the centre (but not very close to it) lose out - they are neither very enticing to those who can work from home two days a week nor close enough to the centre to be the best location for most of those who need to work near the centre every day.

At locations far from the centre where structures had not been built before the change in work from opportunities land values rise. In aggregate the total value of land falls - as illustrated in figure 2 which shows how aggregate land values evolve relative to the base case over time. In aggregate land values fall by about 20% and stay that much lower.The drop in house prices, by distance from the centre, just after work from home opportunities rise, has the same general shape as the fall in land prices. The second panel of figure 1 shows a fall of around 10% in home prices at most locations (here we consider those areas where the great majority of the population live). This fall is significantly smaller than the fall in land prices because structures – whose value changes little – make up around half the value of homes in most locations. As with the impact on land prices, house values do not fall most at the centre, but some way from it. The second panel of figure 2 shows over time average house prices are persistently lower by just over 10%.

Figure 3 show the evolution of aggregate consumption and investment. Here there is a sharp decline in consumption in the initial year after the potential for the higher paid to work from home emerges. In this first year there is a sharp rise in investment in new structures which requires aggregate consumption to be initially lower by nearly 2.5%. Once that extra residential capital is in place consumption moves back up and continues to grow at a rate very close to the pre-shock rate of 3%.

Figure 4 shows the path for the flow of utility each period for the lower and higher wage workers. The flow of utility initially falls for lower paid workers (who cut consumption a bit to finance higher investment that has become more profitable) but then moves to a level slightly above the base case. Lifetime utility is higher because the fall of first year utility of about 0.5% in the initial period is followed by utility in each year thereafter being higher

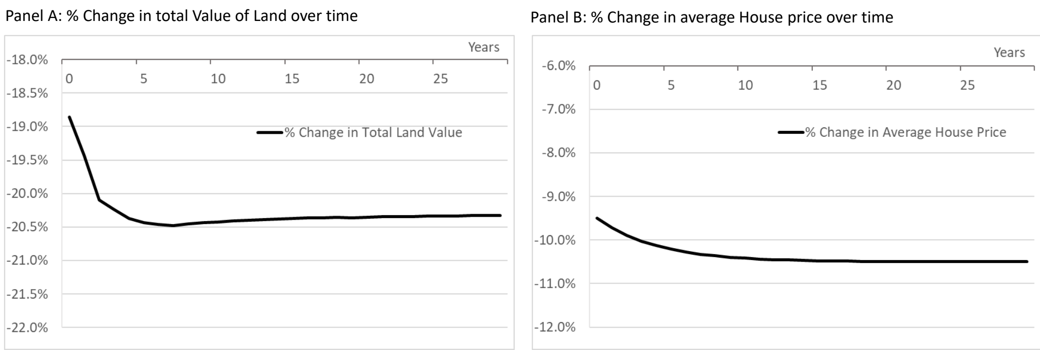

Figure 2: % Change in the total value of Land Wealth and average House prices over time. The changes are a result of a shock that lowers the cost of working from home relative to the balance growth path

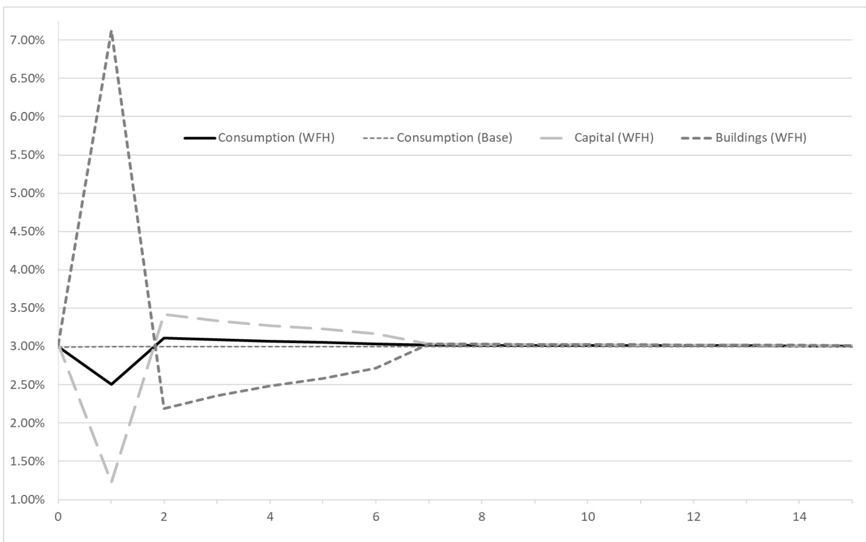

Figure 3: % Growth in Total Consumption Expenditure over time. The changes are a result of a shock that lowers the cost of working from home relative to the balance growth path

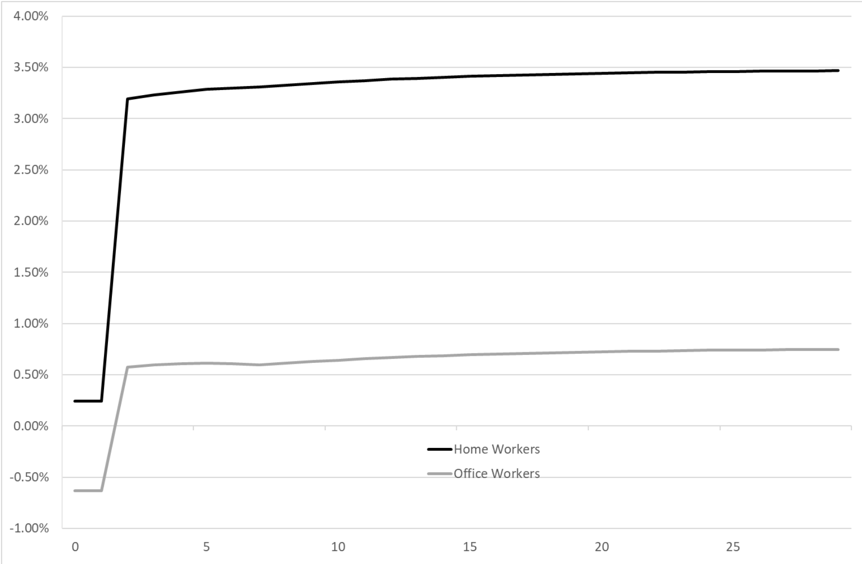

Figure 4: % Change in Instantaneous Utility by Worker Type over time. The changes are a result of a shock that lowers the cost of working from home relative to the balance growth path

by about 0.5%. For higher paid workers who are the ones able to take advantage of work from home the gains in utility are much higher. There is no fall in the flow of utility in the first year and once more work from home becomes a reality (after year 1) utility is about 3.2% higher each period thereafter.

If the ability to work from home before the new opportunities arise were to have been equal (as we have assumed) then people of higher and lower wages would have been distributed in equal proportions at all locations But that changes completely after work from home opportunities become far greater for the better off. After that there is complete segregation with the higher paid moving further out and the less well paid reacting to the change in relative prices of housing by moving further towards the centre. Beyond some distance from the centre only higher paid households live; inside a circle of that radius only lower paid households live. This distance from the centre that becomes the divide between home and office workers is around half way between the centre and the pre-existing edge of residential development. This complete differentiation by location triggers a marked change in the rental gradient with respect to distance. Figure 5 shows that with greater ability to work from home the cost of housing with respect to distance from the centre becomes less steep. But there is discontinuity in the slope of that schedule at the point at which those with limited (or no) ability to work from home give way to those who can work from home.

In the calculations of utility shown above we assumed that prior to the greater work from home opportunities there was no difference in the cost of distance for higher and lower paid workers. But in many ways it is natural to think that those who came to have much greater work from home options - who we assume are the better paid - already had somewhat greater opportunities to do that before the sudden large change. That changes the welfare analysis somewhat because if the higher paid had even marginally greater opportunities to work from home the segregation between locations of the lower and higher paid would have already existed. This matters because falls in land (and therefore house) values after the big rise in options to work from home is, on average, somewhat larger for those who lived near the centre. If they are the ones who get no direct benefit from more work from home opportunities that all accrue to the higher paid then the impact on their welfare is slightly worse than shown in figure 4 above while the outcomes for the better paid are better. The distribution of gains therefore becomes even less equal because the changes in value of existing homes is more favourable for those for whom greater working from home becomes feasible. But we find that this effect is actually quite weak and there is not much of an advantage to having lived furher from the centre before the sudden increase in work from home opportunities - only those living right at the edge of residential developments would have done much better.

The impact on density and on the ratio of land to structure at different locations is interesting. The second panel of figure 5 shows density of population close to the centre and also far from it. After the rise in work from home opportunities population density near the centre actually rises, as it does far from the centre. This first feature seems counter-intuitive. What is happening is that those who cannot work from home come to dominate in locations near the centre They are the less well paid and so buy houses using less land (and structure) than the better paid who move out. The net effect is to raise population density at the centre while some of those moving further out go to locations where before there were almost no people living and so density rises.

Panel C of figure 5 shows the land/structure mix in houses by location. The mix of buildings to land is lower after the rise in work from opportunities at most locations. This is because at most locations land values fall while the cost of new structures is unchanged. Panel D shows how the net rental yield (rental yields after depreciation costs) at different locations. At distances further out, the net rental yield falls as more of the return to housing is in the form of capital gains on the land component, see equation (16).

4.2 Off the balanced growth path:

We ran the same simulation where the economy was not on the balanced growth path before the sudden big change in ability of some to work from home. In this simulation house prices relative to the price of consumption goods had been rising because transport improvements could not keep up with rising populations and per capita incomes. But perhaps surprisingly the change, relative to the status quo path of no rise in work from opportunities, of a sudden improvement in those options was very similar to the balanced growth path case considered above. Figures 6 and 7 show what happens to land prices and to the welfare of the two groups of workers with the sudden rise in the options to work from home for the home workers. Those two figures are strikingly similar to figures 1 and 4. In effect the big

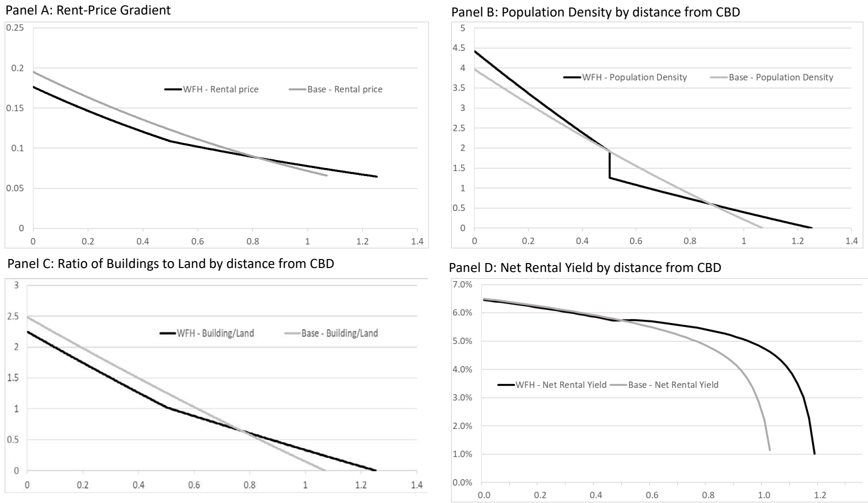

Figure 5: % The Rent Price Gradient, Population Density, ratio of Building Structures to Land and Net Rental Yields before and after a shock that lowers the cost of working from home relative to the balance growth path

changes brought about by more work from home opportunities are the same whether house prices had been rising or were flat before the change.

5 Conclusions

We model the impact of a sudden and substantial rise in the opportunities for some people to work from home. Such opportunities seem to have come as a (welcome) side effect of the Covid pandemic which forced many employers to have employees work from home - something which had far less of an impact on effectiveness than had been thought. These expanded opportunities do not accrue to all, and it seems that on average higher paid workers have the greater opportunities. We model the short and long run impacts of such a change. We use a model calibrated to developed economies and which in past work we find matches well many features of the evolution of house value and the spatial distribution of housing. Our results reveal several things:

Land and house prices decline after a sudden rise in work from home opportunities and across large swathes of the areas where people lived before the change; prices fall by substantial amounts and not just near the centre of cities. Indeed they fall by more at locations not at the urban centre than at those very close to it. Population density may rise at the centre even though work from home opportunities have increased - crucial here is that such opportunities accrue to the better paid.

Welfare gains are significant for workers whose opportunities to work from home rise, who we assume have higher wages and welfare before the change. Lower paid workers who

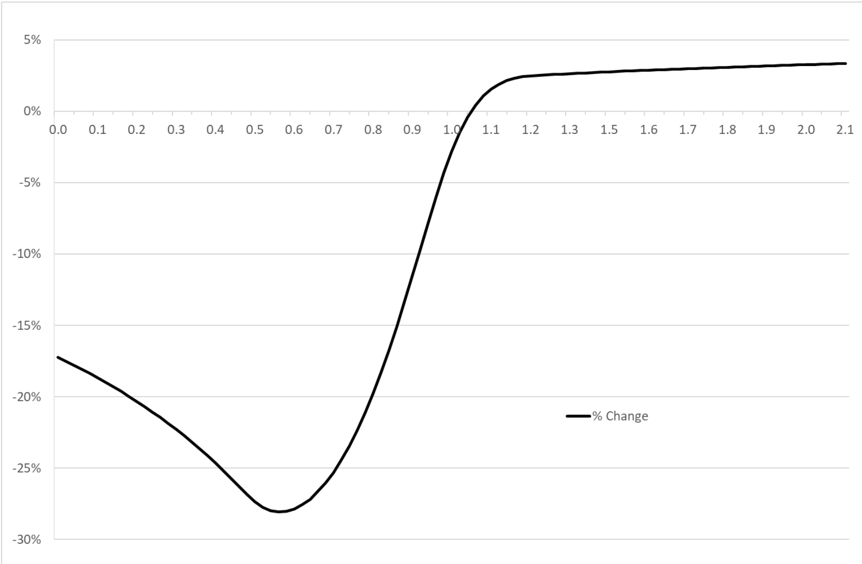

Figure 6: % Change in Land Values by distance from CBD at time $t = 0$. The distance is scaled so that at $t = 0$ the $l_{Edge} = 1$. The changes are a result of a shock that lowers the cost of working from home relative to an economy with rising house prices.

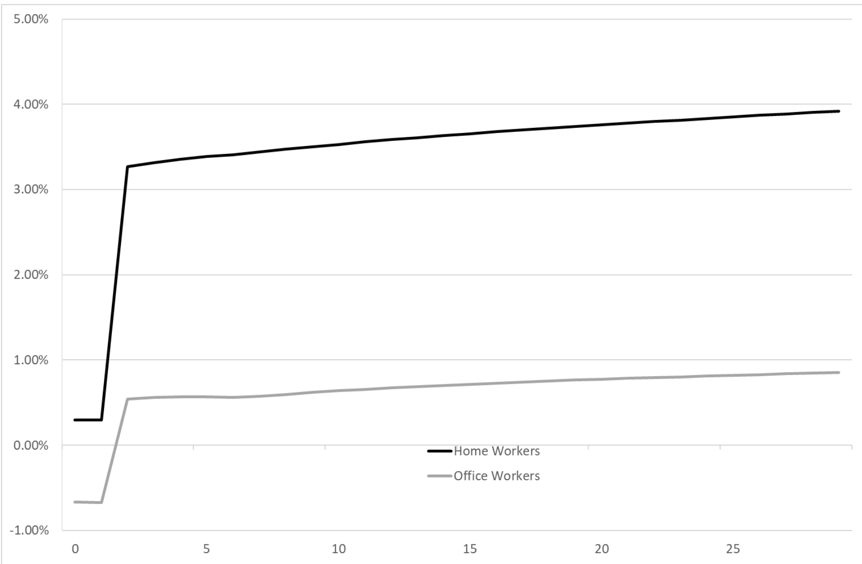

Figure 7: % Change in Instantaneous Utility by Worker Type over time. The changes are a result of a shock that lowers the cost of working from home relative to an economy with rising house prices.

do not see the same rise in ability to work from home do not gain much - but neither do they lose. The gains are significant but not enormous - for the better paid welfare is higher by about 3.5%; for the less well paid (who don't get direct benefits from enhanced ability to work from home) lifetime welfare is about 0.5% higher.

After the change there is a marked shift in location choices - in the absence of any other factors there would be complete segregation if we go from a word where no difference in ability to work from home to one where very substantial differences arise. In a model with no other frictions or other factors at work there would be complete segregation after a difference in work from home opportunities comes; those who can live further out, and only those with no option but to travel to work every day live near to the centre. Such complete segregation is unrealistic and is a feature of the calibrated model only taking on board some features of the location choice. Richer models that have heterogeneity in preferences about other aspects of location would generate less segregation and perhaps also lower impacts on home values of shifts in work from home options.

David Miles
James Sefton

Imperial College, London

References

Adams-Prassl, A., Boneva, T., Golin, M. & Rauh, C. (2020), Working from home: The polarizing workplace, Technical report, VoxEU CEPR Policy Portal.

Adams-Prassl, A., Boneva, T., Golin, M. & Rauh, C. (2022), 'Work that can be done from home: Evidence on variation within and across occupations and industries', *Labour Economics* **74**, 102083.

Ahlfeldt, G. & McMillen, D. P. (2014), New estimates of the elasticity of substitution of land for capital, *in* 'Regional development and globalisation: Best practices', European Regional Science Association, Louvain-la-Neuve. 54th Congress.

Albouy, D., Ehrlich, G. & Liu, Y. (2014), Housing demand and expenditures: How rising rent levels affect behaviour and cost-of-living over space and time, Technical report, University of Illinois.

Albouy, D., Ehrlich, G. & Liu, Y. (2016), Housing demand, cost-of-living inequality, and the affordability crisis, Working Paper 22816, National Bureau of Economic Research.

Barrero, J. M., Bloom, N. & Davis, S. J. (2021), Why working from home will stick, Working Paper 28731, National Bureau of Economic Research.

Chen, Y., Cortés, P., Koşar, G., Pan, J. & Zafar, B. (2023), The impact of COVID-19 on workers' expectations and preferences for remote work, Working Paper 30941, National Bureau of Economic Research.

Davis, M. A., Ghent, A. C. & Gregory, J. M. (2021), The work-from-home technology boon and its consequences, Working Paper 28461, National Bureau of Economic Research.

Davis, M. A. & Heathcote, J. (2005), 'Housing and the business cycle', *International Economic Review* **46**(3), 751–784.

Delventhal, M. & Parkhomenko, A. (2020), 'Spatial implications of telecommuting', *Covid-Economics* **61**.

Ermisch, J. F., Findlay, J. & Gibb, K. (1996), 'The price elasticity of housing demand in britain: issues of sample selection', *Journal of Housing Economics* **5**(1), 64–86.

Gupta, A., Mittal, V., Peeters, J. & Van Nieuwerburgh, S. (2022), 'Flattening the curve: pandemic-induced revaluation of urban real estate', *Journal of Financial Economics* **146**(2), 594–636.

Hall, R. E. (1988), 'Intertemporal substitution in consumption', *Journal of Political Economy* **96**(2), 339–357.

Jerbashian, V. & Vilalta-Bufí, M. (2022), Working from home in european countries before and during the covid-19 pandemic, Working Paper 9932, CESifo.

Jordà, Ò., Knoll, K., Kuvshinov, D., Schularick, M. & Taylor, A. M. (2019), 'The rate of return on everything, 1870–2015', *The Quarterly Journal of Economics* **134**(3), 1225–1298.

Kiyotaki, N., Michaelides, A. & Nikolov, K. (2011), 'Winners and losers in housing markets', *Journal of Money, Credit and Banking* **43**(2-3), 255–296.

Miles, D. & Sefton, J. (2021), 'House prices and growth with fixed land supply', *The Economic Journal* **131**(636), 1815–1848.

Muth, R. F. (1971), 'The derived demand for urban residential land', *Urban studies* **8**(3), 243–254.

Ogaki, M. & Reinhart, C. M. (1998), 'Measuring intertemporal substitution: The role of durable goods', *Journal of Political Economy* **106**(5), 1078–1098.

Rognlie, M. (2016), 'Deciphering the fall and rise in the net capital share: Accumulation or scarcity?', *Brookings papers on economic activity* **2015**(1), 1–69.

Taneja, S., Mizen, P. & Bloom, N. (2021), Working from home is revolutionising the uk labour market, Technical report, VoxEU CEPR Policy Portal.

Thorsnes, P. (1997), 'Consistent estimates of the elasticity of substitution between land and non-land inputs in the production of housing', *Journal of Urban Economics* **42**(1), 98–108.

Van Nieuwerburgh, S. & Weill, P.-O. (2010), 'Why has house price dispersion gone up?', *The Review of Economic Studies* **77**(4), 1567–1606.

Vissing-Jørgensen, A. (2002), 'Limited asset market participation and the elasticity of intertemporal substitution', *Journal of Political Economy* **110**(4), 825–853.