Labor Migration Networks: An Agent-Based Approach with Remote Dynamics

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Abstract

The COVID-19 pandemic and resulting economic crisis asymmetrically impacted labor and production across industry sectors. Firms and workers capable of leveraging the technological advancements of the twenty first century have been largely successful in decoupling physical proximity and economic output. Other sectors experienced severe negative impacts of social distancing. This bimodal effect, paired with lasting impacts of the pandemic, will radically alter labor-firm relationships in the coming years. Historical models of migration have not focused on firm-labor colocation dynamics. In this paper I develop an agent-based model of networked migration supporting multitudinous combinations of heterogenous locations, firms, industry sectors, and laborers suitable for examining migration in both the pre-pandemic and next normal worlds.

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1 Introduction

The COVID-19 pandemic and resulting economic crisis has radically altered our social norms. In particular, social distancing measures implemented as a means of controlling the pandemic radically had spillover effects that radically, if asymmetrically, blended our work and home lives. Firms in sectors capable of leveraging the technological advancements of the 21st century were largely successful in decoupling physical proximity and economic output (Bick et al., 2021). Firms within sectors incapable of leveraging remote working dynamics experienced economic hardship (Bartik et al., 2020) in the face of supply and demand shocks related to the pandemic induced economic crisis.

As it became clear that the measures mean to slow the spread of the novel coronavirus would last significantly longer than initially expected, firms capable of decoupling their labor from the firm's physical location began investing heavily in technology to support a prolonged period of remote work. The flexibility the new working conditions provided led to a widespread migration and resulting housing boom. Anecdotally, workers reaching inflection points in their life situation, coupled with a decline in local amenities, and with the constraint of a daily commute removed have migrated from cities to nearby suburbs or rural areas at an accelerated pace.

In sectors where remote working has become a comfortable choice, the bell cannot be unrung. Despite the preference for onsite work for many companies, the prevalence of remote work- and labor's preference for it- has forced an adoption of hybrid work from home models for nearly all job families where physical location is not a necessary pre-condition of productivity. This model, coupled with the amenities provided by urban centers, generally poses some geographical limits on the urban to suburban migration. This effect is amplified in cities where the cost of living is high (Ramani & Bloom, 2022).

While we appear to be reaching some initial steady-state remote work arrangements, the future is still uncertain. There are many prescient questions to be studied regarding the shifting population centers. How will the continued urban to rural/suburban migration impact firms and labor in sectors where remote work is rare? To what extent might shifts of labor from high cost of living areas to suburbs and exurbs impact agglomeration effects of industry? Will the asymmetry of telework capable industries exacerbate or improve (in)equality concerns in cities?

The space of this text does not permit me to answer all of these important questions and the innumerable others directly. Instead, I develop an agent-based model (ABM) of migration anchored in the historical economic literature with labor and firms paired via a networked-based aggregate matching function. The modeling choice provides the flexibility to answer the wide ranging questions by offering near limitless simulation parameters. Coupled with the prevalence of micro-data, the model can be instantiated to represent an arbitrary real-world scenario with unlimited numbers of firms, workers, sectors, and locations. Importantly, the model allows for asymmetric remote working dynamics across sectors.

The ABM presented here is symbiotically conditioned using a well understood neo-classical model of urban to rural migration (Moretti, 2010)[1], a method colloquially known as *docking*[2] (R. Axtell, 2000). The paper is structured as follows. I begin in section 2 with a review of the literature. In section 3 I develop the theoretical modelling framework. In section 4 I apply the model to reproduce the general equilibrium results in Moretti's paper. In section 5 I directly replicate section 4 while introducing remote work simultaneous to labor demand shocks. Section 6 concludes.

2 Literature Review

The generative framework of agent based modeling provides a robust world in which simulation can be used to directly produce counter-factual outcomes. R. Axtell (2000) motivates the use of agent based models in various frameworks. In particular, he describes the *docking* framework in which a top-down, neo-classical model is explicitly

[1]Hereafter references to Moretti are to this 2010 manuscript unless otherwise specified

[2]In a forthcoming work I focus on the epistemological and ontological limits of a narrow subset of the approach defined by Axtell where an agent-based model is conditioned by a neo-classical one. The model described in this manuscript is a practical example of the framework I present therein

tied to a bottom-up, agent-based model. The theoretical bounds of this framework are further interrogated by (Modig, forthcoming). R. L. Axtell and Farmer (2022) discuss the empirical grounding of agent economies within this vein. In particular, the model presented within this paper and employed within this framework rests within the *qualitative* reproduction of aggregate patterns.

Several ABMs have been employed using the various flavors of the empirical grounding framework discussed by R. L. Axtell and Farmer (2022). Wicaksono and Mansury (2020) employ the methodology in the context of wealth inequality and college attainment. Mandel (2012) discusses agent-based dynamics in a general equilibrium model as it pertains to Arrow-Debreu economies.

This text is primarily concerned with labor migration in the context of a post-COVID world. As noted, it is rooted in the conceptual *docking* framework. Here, the Moretti framework of labor migration is the general equilibrium model upon which the ABM is conditioned. Moretti presents a two-location, two sector model of labor migration initially proposed by Harris and Todaro (1970) as a model of rural-urban migration.

Despite the 50 year history of partial and general equilibrium models of labor migration, few agent-based models of labor migration have been published. Klabunde and Willekens (2016) review decision making not just within labor migration models, but generally within agent-based models of migration. Few ABMs reviewed are explicitly labor migration models. García-Díaz and Moreno-Monroy (2012) and Espíndola et al. (2006) are the only ABMs reviewed in the vein of the Todaro-Harris model of migration.

Espíndola et al. (2006) present a simplified model of rural-urban migration inspired by Todaro-Harris. The ABM presented by Espíndola et al. (2006) is model within which the decision-making process of the agent is based on the decisions of agents in the so called *Moore* neighborhood of the agent of interest. This model is perhaps closest to the one presented within this paper; however, it lacks several key attributes. In particular, the Espíndola et al. model only models two sectors and two locations, while the model presented here can be generalized to any number of sectors and locations. Contrary to the model presented by Espíndola et al. (2006), decision making is not based on the influence of a local social network, but rather the direct utility maximation problem proposed by Moretti.

While Espíndola et al. (2006) leverage the primitive social network utilized by Schelling (1969) to understand how local information can produce emergent properties at the macro level, the network model presented herein is more sophisticated. In particular, the social network is constructed via the labor flow network proposed by López et al. (2020). That is, where the simple approach utilizes a basic local network, my approach matches labor and firms via a social network estimated by the projection of a bipartite firm-labor network.

The macroeconomic effects of the COVID-19 pandemic have been well-studied. The focus within this paper is not on the direct economic impacts, but rather on the long-term implications for remote work and the *new normal* as it pertains to labor dynamics. Vyas (2022) discusses the future impacts *blue collar* versus *white collar* work in a post-COVID world. Haslag and Weagley (2021) explore the underlying motivations for migration as it pertains to high income versus low income households. Bick et al. (2021) use a novel data set to argue that observed heterogeneity in remote working dynamics may be applicable to permanent changes. Florida et al. (2023) details the attraction of cities- even in a post-COVID world. In that vein, Ramani and Bloom (2022) discusses the "donut" effect that WFH has on major metropolitan locations relative to small cities.

Agent-based models of migration are well studied- though models of labor migration in particular are sparse. Similarly, models of labor migration have a rich neo-classical academic literature. However, to the best of my knowledge, the proposed agent-based model is novel within the labor migration literature. Beyond the novelty of labor migration within the agent-based literature, this model also implements a framework for understanding remote labor dynamics in a post-COVID world.

3 Model Description

This model[3] seeks to provide a framework for understanding firm and labor migration in a setting where remote work is both possible and asymmetric across sectors. Migration within the model is subject to location-specific constraints. Job searching is governed by a matching function that is restricted to a labor flow network (LFN) among connected firms, introduced by López et al. (2020). The LFN is defined by the firm-firm network projected from the labor-firm bipartite graph. This approach agglomerates personal connections via coworkers in lieu of attempting to build a direct social network which is both computationally expensive and subject to bias. This model is anchored in the framework of an existing, well-cited General Equilibrium model Moretti; however, the ABM approach accommodates a near limitless parameter space which can be instantiated using micro-data of interest for a large variety of simulation-based economic studies.

3.1 Location

A variable number of locations are specified at model instantiation, parameterized as $L(A, X, k)$, where A is a measure of local amenities, X is a locality-specific productivity shifter, and $k \geq 0$ is the housing elasticity. At the extreme, $k = 0$ indicates perfectly elastic housing supply. All values are supplied exogenously prior to $t = 0$ and do not shift for the duration of the simulation.

Each worker associated with the location consumes 1 unit of housing. Housing supply at Location c is given by

$$r_l = z + k_l N_l \tag{1}$$

Where N_l is the log of total labor in Location l at time t. The parameter z can be exogenously supplied to adjust the rent floor within the Location.

[3] The model is currently implemented in Python accessible at https://github.com/modigzd/laborFlow

3.2 Firm

A variable number of firms are specified prior to $t = 0$ during initial parameterization. Firms are assumed to be perfectly mobile, and assess productivity in all world locations based on current appropriate parameters at time, t, with $Pr(\beta)$. Firm productivity is Cobb-Douglas with constant returns to scale:

$$Y_f = X_f X_l N_f^{\alpha} K_f^{1-\alpha} \tag{2}$$

Where X_l is the location-specific productivity shifter and X_f is an exogenously supplied productivity shifter for Firm f, endowed prior to $t = 0$. N_f are the number of workers employed by the Firm at time t. K_f is the firm capital, exogenously parameterized prior to time t. The output elasticity of labor is given by α.

Firms are price takers, and wage is paid in marginal product:

$$w_f = X_f X_l \alpha N_f^{\alpha-1} K_f^{1-\alpha} \tag{3}$$

Labor within Firm f are paid equal wages. A Firms' labor is homogeneous, with a static sector.

Firm profit is given by:

$$\pi_f = pX_f X_l \alpha N_f^{\alpha-1} K_f^{1-\alpha} - max\{\bar{w}_l, w_f\}N - k_l K \tag{4}$$

Where $\bar{w}_l$ is the mean wage supplied by competing firms within the sector of Firm f in Location l at time t, and p is the unit price of the good produced by the Firm.

A firm will seek to hire workers such that profit is maximized. The optimal number of workers a firm employs is the solution to:

$$\frac{\partial \pi}{\partial N} = \alpha p X N^{\alpha-1} K^{\beta} - max\{\bar{w}_l, w_f\} \tag{5}$$

Setting equation 5 equal to 0 and rearranging:

$$N^* = \left\lceil e^{\frac{log(max\{\bar{w}_l, w_f\}) - log(\alpha p X_f X_l) - (1-\alpha) log(K)}{\alpha - 1}} \right\rceil \tag{6}$$

During the course of the simulation it is possible that a given Firm will lose all of its employees. The Firm may eventually be re-populated by an entrepreneurial worker. In this way, the number of firms per sector are capped for the duration of the simulation to the initialized number of sector-specific firms. Firms with zero employees during any time step are excluded from the associated statistics.

Firms evaluate their profit in each location with $Pr(\beta)$ at each time, t based on instantaneous Firm and Location parameters. Firms assume that if they choose to relocate, all workers will relocate with them - a condition that is not necessarily satisfied after the decision has been made as all labor associated with the firm re-evaluates their employment prospects prior to choosing to follow the firm to the new location.

3.3 Labor

A fixed number of workers are specified prior to $t = 0$ during initial parameterization. Workers maximize their utility across all within-sector firms that are directly connected to either the workers current or last employer with $Pr(\alpha) \geq \alpha$ at each time step according to:

$$u_{ilf} = w_f - r_l + A_l + e_{il} \tag{7}$$

Where w_f is the endogenous wage offered by Firm f, r_l is the cost of housing in location l, A_l is a local measure of amenities in location l, and e_{il} represents Worker i's idiosyncratic preference for location l. Idiosyncratic location preferences for each worker, i, in location, l, are drawn from:

$$e_{il} \sim U[s_l, q_l] \tag{8}$$

Where s_l and q_l are location specific endpoints exogenously supplied prior to $t = 0$. Idiosyncratic location preferences do not change during the course of the simulation.

Note that the worker and the firm may or may not be physically located within the same location. Equation (9) governs the process by which remote work arrangements are agreed upon. In the event that a firm and worker enter into a mutual remote work agreement, the worker chooses their physical location by maximizing their idiosyncratic location preferences.

A few additional modeling choices should be made clear. Excepting labor associated with a Firm relocating, a worker that engages in a job search may not return to their current firm. Because labor maximizes their utility across multiple parameters, they may separate from the workforce entirely. These choices provide additional intuition for the probability, $Pr(\alpha) \geq \alpha$, with which the worker engages in a job search. Namely, this probability can be considered the probability with which a worker is fired from their current role. Because firms are perfectly mobile, there exists some probability, β, that the firm will evaluate their location and decide to move. In the event that a firm chooses to move, all workers associated with the firm will perform a job search, whether or not the workers were separated prior to the move. In only this case, workers may return to their firm.

3.4 Aggregate Matching Function

Within the model, each worker has at most two firm connections: their previous firm and their current firm. A bipartite graph is drawn from the firm-labor connections, which projects a firm-firm network through which labor can search for new firms to move, when activated with probability α. Labor's search is restricted to only to firms sharing a direct edge with the current or previous employer. I refer to the local network as a labor flow network (LFN) using the terminology introduced by López et al. (2020). The approach within this manuscript is endogenous- the LFN updates at each time step. This expands the exogenously supplied LFN utilized by López et al. (2020) under their empirical study.

There exists some possibility that a worker will get stuck in an inescapable well due to lack of connected firms. For this reason, and to introduce some randomization, with some probability τ, the worker maximize their utility across both connected firms as well as some random selection of firms within its sector.

In rare cases the worker will have no associated firm. In this case, the worker will search for employment amongst all firms within their sector.

3.5 Remote Dynamics

The model implements remote dynamics as a function of probability distributions among both firms and labor. Firm- and labor-specific remote distributions are exogenously supplied. Regardless of sector, each worker, i, randomly draws a remote preference θ_i on the interval $[0,\ 1]$ from $\sim N(\mu_w,\ \sigma_w)$.

Unlike labor remote preferences which are agnostic to sector, firm remote preferences are sector-specific. Each firm, f, in sector, s, will randomly draw a remote preference φ_f^s on the interval $[0,\ 1]$ from $\sim N(\mu_f^s,\ .075)$. The standardized Gaussian noise parameter provides some tolerance for firm-specific remote preference within each sector while broadly controlling remote preferences by sector. This flexibility allows for the simultaneous parameterization of sectors such as service or industrial, where remote work opportunities may be minimal, and sectors where remote work may be ubiquitous.

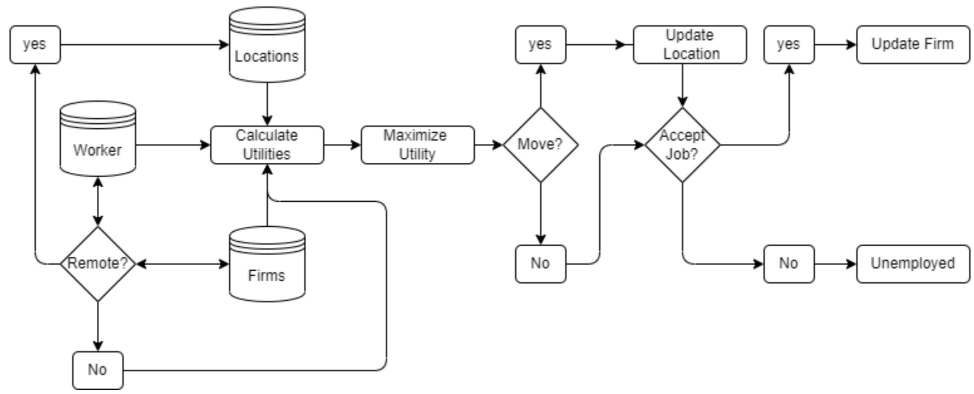
Each firm-worker pair comes to a remote work agreement during the worker search process. The agreement- wfh or onsite -persists for as long as the worker remains employed by the firm. The process is governed by separate random draws from $\varphi \sim U[0,\ 1]$ and $\theta \sim U[0,\ 1]$ such that

$$WFH_{i,f} = \begin{cases} 1 & \text{if } \theta_i \geq \theta \text{ and } \varphi_f^s \geq \varphi \\ 0, & \text{otherwise} \end{cases} \tag{9}$$

It should be noted that the agreement of a remote working arrangement between the worker and the firm does not guarantee that a worker will choose against co-location with the firm. Instead, the existence of a remote work agreement simply allows the worker to maximize their utility according to equation (7) within the firm across all locations within the model. That is, a remote work arrangement expands the set of available utilities to maximize across by $n_l - 1$, holding all other parameters constant. If a firm and worker enter a remote work arrangement, the worker will reside in the locality that maximizes their utility until such a time that the worker separates from their firm.

3.6 Evaluation and Decision Making

At each time step, $\approx N_F \cdot \beta$ randomly chosen firms and $\geq N_W \cdot \alpha$ randomly selected workers will evaluate their current conditions and seek to maximize their utility. The decision-making process for each agent is represented in the figure below.



Labor Decision Making Process

4 Spatial Equillibrium

The model is evaluated in two parts. First, the model is calibrated by docking it to Morreti's neo-classical equilibrium-based model of migration. Here, I focus only on the case of exogenous shocks as discussed in sections 3.1 and 3.2 of his work. Both models are two location models. In section 3.1 the firms and agents are homogeneous in skill. In section 3.2 he explores a 2-sector heterogeneous model of skilled and unskilled labor.

After establishing the boundaries of the ABM and neo-classical equilibrium framework, I then introduce remote shocks in section 5 by implementing remote work policies. Here, the ABM can depart from the rigid neo-classical framework.

Each simulation of the model is first run until equilibrium is achieved according to the initial parameters supplied. Shocks are then applied to the model and it is allowed to run until it reaches long-run equilibrium. For each scenario explored, 50 separate simulations are performed.

4.1 Model Calibration

Because the model detailed in this manuscript is agent-based, several parameters need to be supplied exogenously[4]. Due to computational limitations, I scale the approximately 157 million people in the U.S. workforce[5] to 1,570 agents within the model. Similarly, the model is instantiated with 110 firms. Due to the software implementation, the number of workers within the model is constant across time. While there is an upper limit on the number of firms (110), there are cases when some firms employ 0 agents over some number of simulated steps in time. For time periods where a firm size is 0, it is not counted against the total number of current firms in the model.

Both firms and workers are free to re-evaluate their location during the simulation when activated. Approximately 5% of the workforce is separated from their attached firm per time-step, which corresponds to a 1 month. These workers immediately begin searching for jobs. Any worker that does not find employment will continue to search each time period until they do. During any given simulation step, a firm has an approximately 1% chance of re-evaluating it's location and re-locating to a more favorable location (see section 3.2 for the firm's profit maximization problem). If the firm does choose to re-locate, all of the attached workers will be given the ability to search for jobs *risk free*. If they find a more favorable firm, they will move. If not, they are allowed to maintain their employment with their current firm.

Unless otherwise noted, workers will have a slight idiosyncratic preference for location A. This follows from the uniform draw on the interval $[0, 1.5]$ in location A vs $[-1.5, 1.5]$ for location B.

[4]Exact parameters for each model explored within this paper can be found in the scripts generating results presented within this paper at https://github.com/modigzd/laborMigrationPapers

[5]Bureau of Labor Statustics, U.S. Department of Labor, Occupational Outlook Handbook, Table A-1. Employment status of the civilian population by sex and age, https://www.bls.gov/news.release/empsit.t01.htm (visited 11/21/2022)

4.2 Homogeneous Labor

Following Moretti, I first explore the impact of exogenous shocks on a two location model where skill is homogeneous. Figures and tables corresponding to this section can be found in Appendix A.

4.2.1 Labor Demand Shock

Here, any firm located in location B will experience a productivity shock. In the neo-classical case, the nominal wage will increase due to the increase in productivity. Despite an increase in rent driven by the labor migration to the more productive location, the real wage will still increase as productivity is not completely offset by the rent increase. The outflow of workers to location B raises the real wage in location A, assuming firm productivity is constant in A pre- and post-shock.

The ABM reproduces the results seen for location B. Firms in location B become significantly more productive (see figure A.2.1.3). As a result, the mean nominal and real wages increases significantly.

At first glance, the mean real and nominal wages decrease significantly in location A (see figures A.2.1.4 and A.2.1.5). This deviation from the neo-classical model is largely explained by the steep drop in employment rate (see figure A.2.1.8). When only considering the employed workers within location A, the mean nominal and real wages are indistinguishable from pre-shock equilibrium due to the error bounds (see figures A.2.1.6 and A.2.1.7). Within this scenario, nearly all of the workers in the model have moved to location B, with only approximately 10% of the total population choosing to remain in location A (see table A.1.1.3).

The variation in wage across the simulations in location A can be explained by the movement of firms from location A to location B (see figure A.2.1.2). When a firm becomes large enough to offer a competitive wage in location B relative to the mean wage in location A, it will migrate in order to experience the significant productivity increase. Workers are given a choice to follow the firm. In most cases, the workers will choose to go with the firm to capture the higher nominal wage, as they base their decisions on nominal rather than real wage. Because firms re-evaluate their location randomly and relatively infrequently, the result is a variance in outcomes in the long run.

4.2.2 Incidence: Idiosyncratic Location Preferences

Within this section, I explore the limiting cases of idiosyncratic preference: no preference, $s = 0$, and immutable preference, $s = \infty$. In the neo-classical model, real wage in location A is unchanged if labor is unwilling to migrate. This follows from the fact that nominal wage does not change and the inability to migrate holds the rent fixed. Nominal wage in location B increases due to the productivity shock. Because workers will not migrate, rent remains constant and therefore real wage increases by the full amount.

When considering only the employed workers, the ABM reproduces the dynamics of the neo-classical model (see figures A.2.2.6, A.2.2.7, A.2.3.6, and A.2.3.7). If the effects of unemployment are considered, the ABM only replicates the docked model in location B where unemployment is minimal (see figures A.2.2.4, A.2.2.5, A.2.3.4, and A.2.3.5).

Elevated unemployment rates in location A lead to an substantial drop in both nominal and real wages in location A as the jobless agents lack of wage drops the location average. This result is driven by the migration of the finite number of firms in the model. Because of the profit-maximizing hiring decisions, firms will refrain from hiring when the added cost of labor exceeds the additional production the labor provides. When labor is perfectly mobile, the only difference in the profit maximization problem between locations is the location-specific productivity shifter. Firms in location B have excess hiring capacity relative to A, and generate more profit than a comparable firm in the other location.

When considering whether to re-locate, a firm must consider the hypothetical of paying a competitive wage[6]. Due to the high wages offered in location B, this

[6]Defined as the maximum of the average wage in the location or the wage they would offer based on their size. See eq. 4

consideration only makes sense when a firm becomes sufficiently large that they can expect to pay elevated wages and still be more profitable than they would be in location A. Increasing rent is ultimately the barrier to movement for labor, even if they draw no wage.

4.2.3 Incidence: Housing Elasticity

In the general equilibrium model when housing is inelastic[7], $k = \infty$, location B will become more productive, while productivity in location A will remain unchanged. The inability to build more houses in either location is functionally equivalent to the case where labor preferences are immutable, $s = \infty$.

Focusing only on the employed, nominal wages increase in location B and remain constant in location A, consistent with Moretti. The drastic decrease in employment rate (see table A.1.1.1 and figures A.2.4.8 and A.2.5.8) in location A implies that the average resident of A is considerably worse off after the shock- a fact not addressed in the neo-classical model.

Here, the ABM reproduces the firm productivity result, as can be seen in the mean profit per firm. As a result, nominal and real wages increase in location B. This is demonstrated in figures A.2.4.3 and A.2.5.3.

Firms are not bound by the land-use constraint. As in the case when $s = \infty$, firms will migrate to location B when they become sufficiently large. This, coupled with the computational framework that forces $k >> 0$ (vs $k = \infty$), results in some departures from the neo-classical results when the unemployed are considered. The high rate of unemployment in location A causes nominal and real wages to fall as firms migrate from location A to location B.

In the general equilibrium case, when housing is infinitely elastic, $k = 0$, real wages increase in location B by the full amount of the shock. Moretti notes that real wages increase in location A as well, but less so than in B. The result for location B is captured

[7] Computational limits of the ABM framework do not allow for a perfectly infinite housing supply. Instead a very high, computationally feasible k must be substituted.

exactly by the docked ABM. The described behaviour in location A is initially captured by the ABM (considering all workers); however, in the long run nominal wages decrease slightly in location A (though within the error bands they are indistinguishable from the pre-shock wages). Once again, the main driver of this discrepancy is the migration of firms to location B to realize a productivity gain when they become sufficiently large to offer a competitive wage. Employment rates remain a problem in location A for this scenario, and average welfare is substantially affected.

4.3 Heterogeneous Labor

The heterogeneous case extends the homogeneous case by including both skilled and unskilled labor. In order to comport with the neo-classical model, the skilled and unskilled sectors remain distinct from each other. Both firm and labor agents retain their sector endowment for the duration of each simulation. Within this section, two cases are explored- an even number of skilled and unskilled labor and the case where there are more unskilled than skilled workers.

Figures and tables corresponding to this section can be found in Appendix B.

4.3.1 Labor Demand Shock

A labor demand shock is applied only to the skilled sector in location B. Holding all other factors equal, a skilled firm in location B pays a higher wage than it's counterpart in location A, as was shown in section 4.2.1. A natural migration will then occur for skilled workers from location A to location B. The effects of change in rent will spill over into the unskilled sector despite the lack of direct labor demand shock applied therein. This dynamic will impact the flow of skilled workers, relative to the homogeneous case.

The effects of these dynamics accompanied by the added frictions introduced by varying housing elasticities are explored. Unlike in section 4.2.3, the limiting cases $k = 0$ and $k = \infty$ are not directly interrogated. Instead, the flow of labor is explored with varying degrees of friction in order to understand spillover impacts between labor skill groups more narrowly.

The ABM approach also allows for the effects of varying ratios of labor populations to be explored. In addition to considering the effects of housing elasticity when considering an even number of skilled/unskilled workers, the same scenarios are analyzed when unskilled workers comprise 70% of the labor pool.

4.3.2 High Housing Elasticity

In the general equilibrium model when housing elasticity is high (k is low), the localized economic shock experienced in location B will draw skilled workers with minimal friction. As unskilled workers in location B do not experience a similar productivity shock, their real wage decreases as skilled labor drives a rent increase. As a result, unskilled labor will begin migrating to location A until equilibrium is achieved.

Turning attention first to the case where there is an even number of skilled an unskilled workers in the model, the results of the ABM broadly align with the GE model. Skilled workers experience a large gain in real and nominal wages in location B (see figures B.2.1.4 and B.2.1.5). Skilled and unskilled workers in location A both see the same slight increase in real wage with the decreased rent (see figure B.2.1.1). Unskilled workers in location B see a significant drop in real wages which are indistinguishable in magnitude from the real wages in location A. In equilibrium, rent is approximately equal in both locations; however, the types of workers that comprise each location is varied. While there are some unskilled workers in location B, the location is predominately populated by skilled workers (see table B.1.1.3). The opposite is true for location A.

If unskilled workers outnumber skilled workers, there are additional frictions introduced. Within the simulation parameters, the number of firms scales linearly with the number of workers. This allows for more firms to grow to their profit maximizing capacity. The skilled firms in location B will therefore have excess capacity to hire skilled workers relative to the case when there are an even number of skilled an unskilled workers. The increase in nominal and real wage then draws nearly all of the skilled workers in the model to location B. Unskilled workers in both locations have approximately the same nominal wage. All workers have slight idiosyncratic preferences for location A. Therefore, some excess portion of the unskilled population chooses to remain in A, despite the slightly lower real wage. In equilibrium, location A has a higher rent than location B (see figure B.2.2.1). This difference is driven by unskilled workers, which comprise the majority of the model.

4.3.3 Low Housing Elasticity

High k (low housing elasticity), limits migration prior to any economic shocks. This results in roughly equal proportions of skilled/unskilled workers in each sector, with more workers in location A due to slight amenity preferences. After the labor demand shock, increased productivity draws skilled firms to location B (see figures B.2.3.2 and B.2.4.2). Skilled labor migrates along with the firms. This causes an outflow of unskilled labor. As a result, unskilled labor sees a decrease in real wage in location B, which is approximately equal to the real wage in location A (an increase from pre-shock equilibrium). Due to the decreased rent, skilled labor that remains in location A sees a slight increase in real wage. These results are observed in the ABM with even skilled and unskilled populations.

As in the case of high housing elasticity, when unskilled labor greatly outnumber skilled labor the additional frictions impact the dynamics. In particular, the movement (or lack thereof) of unskilled labor largely drives the macro outcomes. Rent in location A remains higher than rent in location B (see figure 2.4.1) due to the idiosyncratic preferences of labor. Skilled labor does migrate, following the firms to location B, and experiences the full gain in real wage (see figure 2.4.5). The few skilled laborers that remain in location B experience a sharp drop in real wage. Real wage for unskilled labor is approximately equal across locations. This is driven by a slight exodus of unskilled labor from location A.

5 Spatial Equillibrium with Remote Shocks

The ABM allows for a relatively simple implementation of remote work, the mechanics of which were described in section 3.5.

In order understand the impacts of remote work policies, I re-run all simulations explored in section 4 with the same starting conditions. The primary difference is that at the same time step when the labor demand shock is applied, remote work is also implemented. The simulations are seeded in such a way that each run with a remote shock corresponds exactly to a run with results described in the previous sections.

For the homogeneous labor case, firm remote tolerances are set at near 100%[8]. In the case of heterogeneous labor, the firm tolerance for remote work is asymmetric across sectors. Skilled firms are highly tolerant of remote work. Unskilled firms are generally intolerant of remote work.

5.1 Homogeneous Labor

The existence of remote work in a model makes it possible for a given worker to choose their preferred housing location while drawing the highest possible wage. However, a given worker will not necessarily choose their preferred location due to rent increases associated with the labor migration flow primarily driven by idiosyncratic location preferences amongst more highly paid labor.

Intuitively, the availability of remote work generally results in increased employment rates relative to the baseline case. These impacts vary by sector and location. Tables A.1.1.1 and A.1.1.3 display the employment rates and the total workers across the simulated cases explored within this paper. Appendix A.1 contains tables displaying comparisons for additional relevant statistics.

The general trend in increased employment rates is evident. Because amenities are slightly higher in location A than location B, workers will be drawn to location A absent other frictions. Similarly, firms experience productivity gains in location B and will

[8]Due to the distributional draw, the number of remote workers is unlikely to ever be exactly 100%

migrate under the assumption that they are large enough to pay competitive wages.

5.1.1 Idiosyncratic Location Preferences

In the scenario where idiosyncratic location preferences are infinite, $s = \infty$, WFH shocks have no impact on the total workers in location A or location B (see table A.1.1.3). However, when remote work is an option, location A experiences 2.44 times the employment rate (.80 vs .32) than in the docked model (see table A.1.1.1). A slight decrease in employment rate in location B can be observed. This decrease is explained by remote workers in location A displacing labor in location B.

When WFH is an option, there are more firms in location B than the baseline model. The firms are also much larger, with much greater profits. Despite this, employed workers in both locations receive slightly lower nominal wages (table A.1.1.7) and approximately equal real wages (table A.1.1.6). This result follows because workers have, on average, a slight idiosyncratic preference for location A over location B. They are tolerant of slightly higher rent and slightly lower nominal wage, all other things being equal. Of course, with a decrease in unemployment, more workers are better off in the WFH case overall (see tables A.1.1.4 and A.1.1.5), even if the employed workers have slightly lower nominal wages.

In the case where idiosyncratic location preferences don't exist, $s = 0$, the overwhelming majority of workers are drawn to location B firms offering high wages. As a result, the workers remaining in location A are largely unemployed while the workers located in location B are employed at full capacity (table A.1.1.1). In contrast, when WFH is offered, workers are split between cities almost equally (table A.1.1.3). This is made possible because WFH arrangements ensure that workers in location A are mostly employed – only slightly less so than those in location B. Rent has a stabilizing effect. Real wages in location B are much greater than those in location A (see tables A.1.1.4 and A.1.1.6). This apparent discrepancy is driven by the fact that workers are considering nominal wage rather than real wage when determining their utility.

5.1.2 Housing Elasticity

When $k = \infty$, one would expect identical results to the $s = \infty$ case[9]. However, computational limitations related to the implementation of the agent-based model prevent a truly infinite elasticity of housing. As a result, there is some slight migration within the model, which explain the slight deviations from the results discussed in the $s = \infty$ case that can be seen in the tables in appendix A.1.

The case when housing elasticity is high, $k = 0$, is conceptually similar to the case where workers have no idiosyncratic location preferences. The difference here is that within these simulation parameters workers will have an idiosyncratic preference for location A, on average. Effectively, this means that in the long run slightly more workers will accept a lower nominal wage to remain in the location of their preference. Comparing the post-shock wage ratios by location (tables A.1.1.4-1.1.1.7), it can be seen that this will result in a slightly lower relative real wage between the locations in the $k = 0$ case than the $s = 0$ case.

Despite the ability to migrate freely, not all labor ends up in their preferred location (see table A.1.1.10). As in the docked model, every resident of location A is happy[10]. However, in the WFH case, more than twice the workers in location B have settled in their preferred location. The mean real wage among the employed in location A is 1.3 times the baseline case. However, the general welfare of the workers in location A is much, much greater in the WFH case due to the massive increase in employment rate. This can be seen in the 3.6 times improvement in wage when considering the unemployed as well as the employed (table A.1.1.4).

5.2 Heterogeneous Labor

Recall that within all scenarios explored in this study workers of all skill type have, on average, a slight preference for location A. Post labor demand shock, skilled firms will

[9]There will be differences in the rate of workers residing in their preferred location. The $s = \infty$ case ensures all workers are in their preferred location by design, while the $k = \infty$ case provides distributional idiosyncratic location preferences consistent with the other scenarios explored in this paper

[10]As measured by location residence relative to location preference

migrate to location B once they have become large enough to offer a competitive wage. In doing so, they will greatly boost their productivity as they benefit from the labor demand shock. When remote work is introduced, skilled firms expand the labor pool to all skilled job seekers within the model. Skilled firms therefore face no friction to movement. In the long run, the only firms left in location A can be understood to be recent entrepreneurial start-ups and have not yet evaluated their location preference. When they do, they will move. Firms employing unskilled workers experience no labor shock and are unlikely to migrate absent an inability to offer competitive wages in the current location.

5.2.1 High Housing Elasticity

When k is low, labor migration is minimally impeded by asymmetric housing costs across locations. Skilled labor, drawn by the higher wages offered by firms in location B, will displace unskilled labor. The effect of this displacement varies with the ratio unskilled to skilled workers within the model.

In an environment where remote work is encouraged, eligible labor will tend to migrate to the location defined by idiosyncratic preference, all other factors held equal. A relative disparity in housing costs will ultimately dissuade migration when equilibrium real wage conditions have been met.

Tables B.1.1.3 and B.1.1.4 show the total workers in each location and the real wage of the employed workers across sectors. When housing elasticity is high, considerably more skilled workers reside in location A, relative to the baseline case. Similarly, skilled workers in location A have slightly higher real and nominal wages in the remote case than the baseline case (see tables B.1.1.4-B.1.1.7).

Relative to the baseline, skilled workers in both locations see increases in real wages. In the case where unskilled labor significantly outnumbers skilled labor, this effect is exaggerated in the otherwise less productive location A.

However, skilled workers in the remote case still prefer to draw a lower real wage in location A than B due to their idiosyncratic location preferences[11]. This results in a significant increase in total skilled workers in location A, displacing some unskilled workers (see table B.1.1.3). This displacement results in a slight decrease in real wages for unskilled labor in location A and a corresponding slight increase in real wage in location B. Unskilled workers in location B draw a higher real wage than those in location A, despite not directly benefiting from either the remote or labor demand shocks.

5.2.2 Low Housing Elasticity

When housing elasticity is low (k is high), significant frictions to migration are introduced. In the absence of remote work, skilled workers migrate on net to location B to experience the benefits of the productivity shock. This migration is muted by the relative inability to build new housing across locations. Unskilled labor will therefore only be slightly displaced due to the housing friction.

Because this simulation does not explore the bounds, but rather $k = .5$ and $k = 2$, the results are quite similar. As expected, the net migration of skilled workers is slightly muted in the case where housing elasticity is high. The net result drive similar changes in real and nominal wages.

5.2.3 Preference and Welfare

Because the employment rate across sectors is already high, skilled labor in both locations will see relatively modest increases in real wage when remote shocks are present. When unskilled labor outnumbers skilled labor, the gain in real wage in location A will be exaggerated. This gain will be accompanied by a significant share of the skilled labor in the location associated with their idiosyncratic preference (see tables B.1.1.9 and B.1.1.10).

Unskilled workers in location A will be negatively impacted by the migration of

[11] Table B.1.1.9 shows a 2.4x and 3.9x increase in skilled workers residing in their preferred location for even and uneven scenarios, respectively. Meanwhile, unskilled workers see an overall slight decrease in workers residing in their preferred location.

skilled labor into location A- both in terms of real wage and idiosyncratic location preference. Within location B, the overall number of unskilled workers that prefer that location remains relatively similar to the baseline case. However, they will see a modest increase in their real wage.

6 Conclusion

This manuscript has presented an agent based model of labor migration that largely replicated the dynamics of the general equilibrium model presented by Moretti. Within the docked framework, there were some departures from the neo-classical model. These departures were largely driven by practical considerations in employment rates that are inherent to the ABM framework but necessarily excluded from the neo-classical one. The very low employment rates in section 4.2 do suggest sensitivity to parameterization, a general criticism of the computational ABM approach. Future research using this modelling framework should focus on conditioning the ABM using real world data. Carrella et al. (2020) and Dominicy and Veredas (2013) provide the basis for several approaches to the problem.

The model does provide a parsimonious implementation to the study of labor migration in the context of remote work. Results in section 5 are generally intuitive. *Ceterus paribus*, the availability of remote work results in increased employment rates, happier workers (as judged by the fraction residing in their preferred location), and increased nominal wages in the location that does not experience the productivity shock. Workers will accept reduced real wages in the more desirable location relative to the more productive, but less desirable location. In the heterogeneous case, I find that unskilled workers in the more desirable location are adversely effected by the migration of skilled workers with remote arrangements- both in terms of depressed real wages and desired location preference.

This results presented in this model do not address the case of hybrid work, a growing paradigm (Florida et al., 2023). Because the model does support limitless locations with associated parameterizations, the ABM presented in this paper can be used to support future analysis with restrictions on distance from the office (Ramani & Bloom, 2022) in a hybrid case.

Additionally, because the model supports unlimited sectors, firms, and locations, it is straightforward to extend the analysis to match real world locations and associated industrial sectors.

Finally, the results presented are attached to the conception of labor migration within the two location framework of Moretti. The ABM provides the ability to constrain individual workers and firms in order to interrogate firm-specific policy implications with respect to remote work.

The generative framework that the agent-based paradigm implicitly supports allows for near limitless exploration of the model space. It has been shown that the model of migration presented can be appropriately conditioned by docking it to a well understood neo-classical framework. The symbiotic relationship between the two approaches allows for a robust modelling framework applicable to innumerable real world scenarios and counterfactuals. This affords the opportunity to explore a rich complexity of off-equilibrium dynamics in real-world applications.

A Appendix A: Homogenous Labor

Figures and tables related to homogeneous labor simulations (sections 4.2 and 5.1) can be found here.

A.1 Tables: WFH vs Docked

The tables below display the equilibrium post-shock values of each metric for both the docked and work from home cases.

Table A.1.1.1: Employment Rate

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	0.11	0.87	7.90	1.00	0.92	0.92
s_∞	0.32	0.80	2.48	0.99	0.96	0.97
s_0	0.11	0.87	7.93	1.00	0.94	0.94
k_∞	0.31	0.88	2.79	1.00	0.92	0.92
k_0	0.13	0.82	6.54	0.98	0.90	0.92

Table A.1.1.2: Employed

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	15.10	796.54	52.75	1430.98	596.44	0.42
s_∞	252.02	625.70	2.48	780.36	752.64	0.96
s_0	15.18	676.80	44.58	1431.92	743.18	0.52
k_∞	215.92	702.50	3.25	883.92	709.92	0.80
k_0	13.60	798.18	58.69	1430.44	540.14	0.38

Table A.1.1.3: Total

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	137.72	919.30	6.68	1432.28	650.70	0.45
s_{∞}	784.48	785.00	1.00	785.52	785.00	1.00
s_0	138.08	776.64	5.62	1431.92	793.36	0.55
k_{∞}	686.08	799.92	1.17	883.92	770.08	0.87
k_0	108.28	972.06	8.98	1461.72	597.94	0.41

Table A.1.1.4: Real Wage

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	0.12	0.98	8.2	1.09	1.12	1.03
s_{∞}	0.28	0.92	3.27	1.16	1.14	0.98
s_0	0.12	1.02	8.46	1.09	1.11	1.02
k_{∞}	0.01	0.05	3.61	0.06	0.05	0.95
k_0	0.15e+16	1.43e+16	9.34	1.74e+16	1.6e+16	0.92

Table A.1.1.5: Nominal Wage

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	0.30	3.36	11.20	3.95	3.61	0.91
s_{∞}	0.94	3.07	3.27	3.88	3.78	0.98
s_0	0.30	3.40	11.32	3.96	3.69	0.93
k_{∞}	0.93	3.42	3.69	3.92	3.64	0.93
k_0	0.34	3.17	9.34	3.87	3.56	0.92

Table A.1.1.6: Employed Real Wage

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	1.03	1.14	1.11	1.09	1.22	1.12
s_{∞}	0.88	1.16	1.32	1.17	1.18	1.01
s_0	1.04	1.17	1.13	1.09	1.18	1.09
k_{∞}	0.05	0.06	1.29	0.06	0.06	1.03
k_0	1.16e+16	1.74e+16	1.5	1.78e+16	1.78e+16	1

Table A.1.1.7: Employed Nominal Wage

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	2.53	3.87	1.53	3.95	3.94	1.00
s_∞	2.93	3.86	1.32	3.90	3.95	1.01
s_0	2.56	3.90	1.52	3.96	3.94	1.00
k_∞	2.94	3.89	1.32	3.92	3.95	1.01
k_0	2.58	3.86	1.50	3.95	3.94	1.00

Table A.1.1.8: Remote Workers

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	0	749.70	Inf	0	294.72	Inf
s_∞	0	572.56	Inf	0	478.76	Inf
s_0	0	661.58	Inf	0	322.30	Inf
k_∞	0	669.22	Inf	0	339.34	Inf
k_0	0	758.42	Inf	0	212.50	Inf

Table A.1.1.9: Preferred Location

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	112.20	916.94	8.17	367.38	390.54	1.06
s_∞	784.48	785.00	1.00	785.00	785.00	1.00
s_0	138.08	776.64	5.62	0.00	0.00	–
k_∞	621.36	798.16	1.28	328.18	391.14	1.19
k_0	108.22	968.96	8.95	392.84	389.80	0.99

Table A.1.1.10: Preferred Location Rate

	Location A			Location B		
	Docked	WFH	Ratio	Docked	WFH	Ratio
WFH_{100}	0.81	1	1.22	0.26	0.60	2.34
s_∞	1.00	1	1.00	1.00	1.00	1.00
s_0	1.00	1	1.00	0.00	0.00	–
k_∞	0.91	1	1.10	0.37	0.51	1.37
k_0	1.00	1	1.00	0.27	0.65	2.43

A.2 Plots: Homogenous Labor

A.2.1 Labor Demand Shock

Figure A.2.1.1: Rent

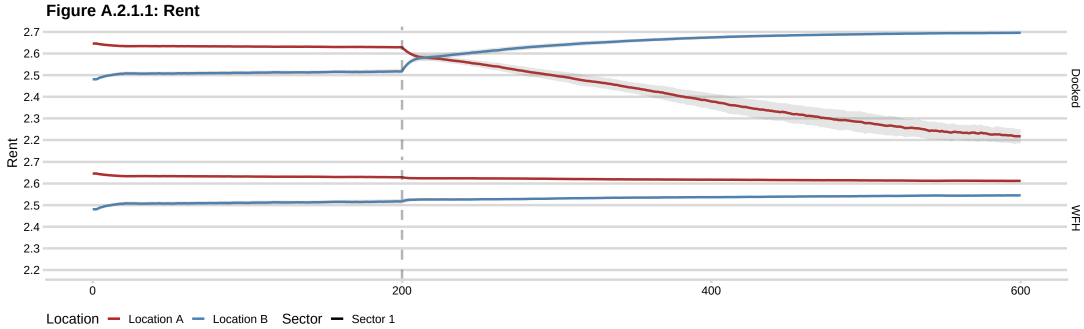


Figure A.2.1.2: Total Firms

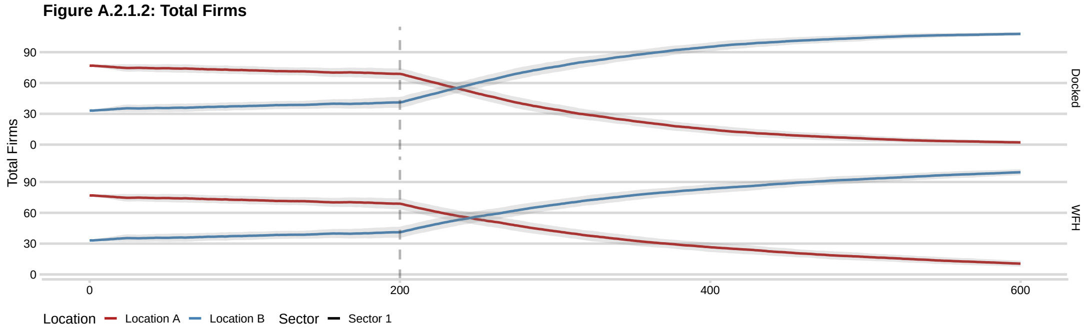


Figure A.2.1.3: Mean Profit

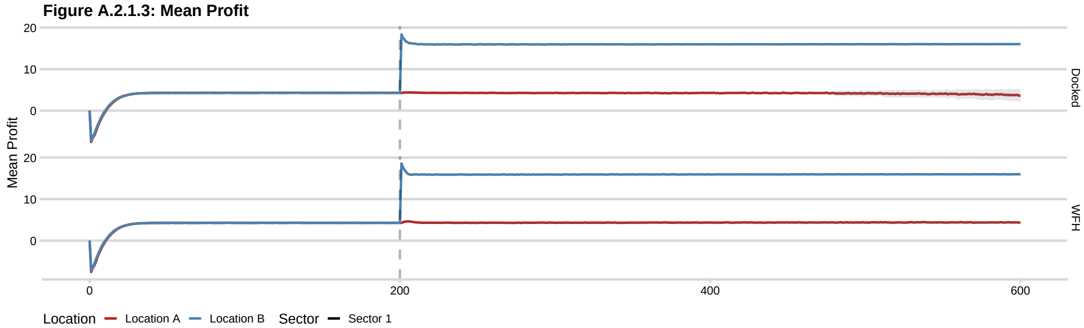


Figure A.2.1.4: Mean Nominal Wage

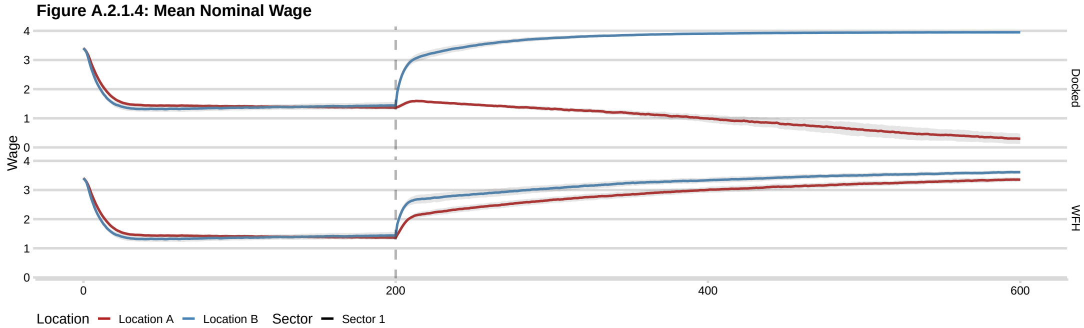


Figure A.2.1.5: Mean Real Wage

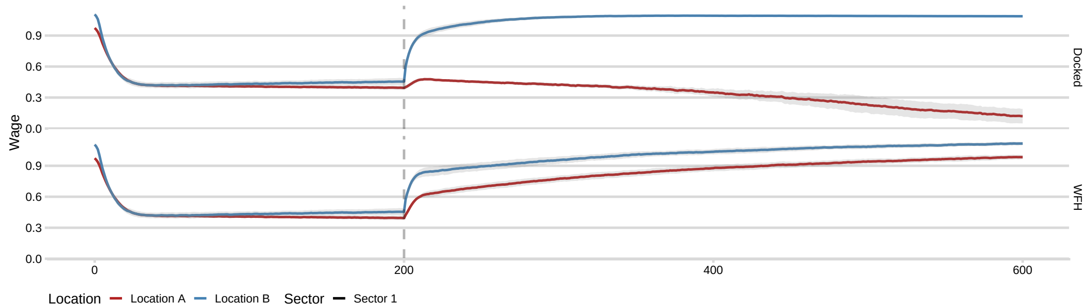


Figure A.2.1.6: Mean Nominal Wage (employed only)

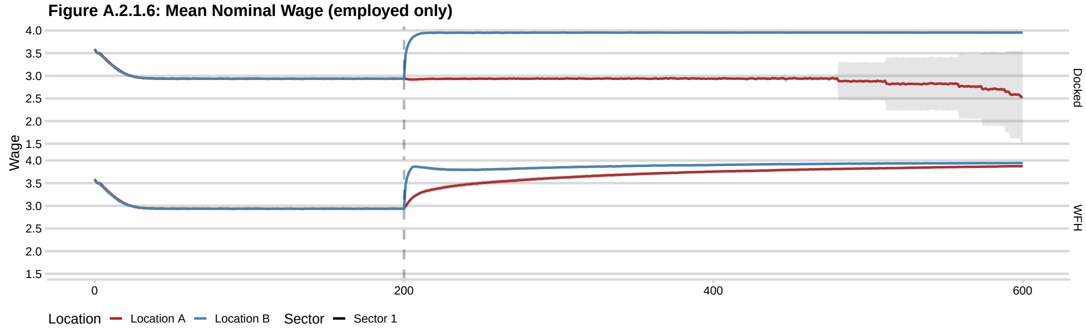


Figure A.2.1.7: Mean Real Wage (employed only)

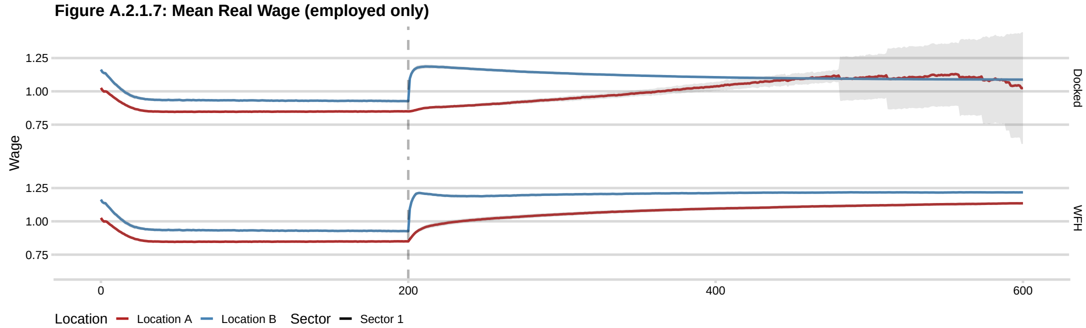


Figure A.2.1.8: Employment Rate

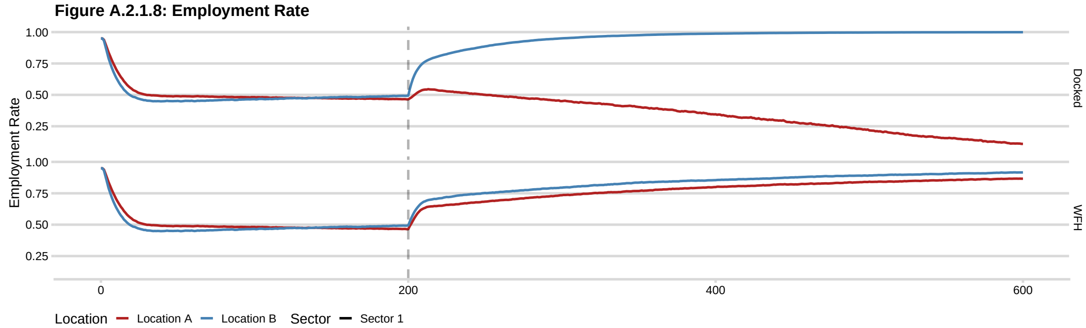
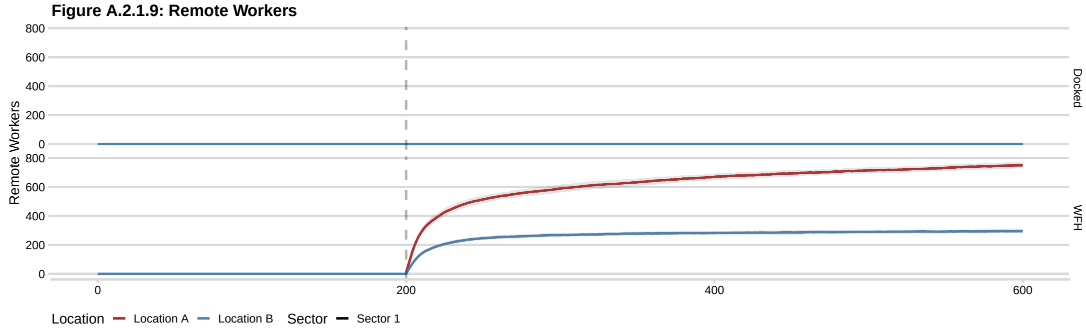


Figure A.2.1.9: Remote Workers



A.2.2 Incidence: Immutable Idiosyncratic Location Preference

Figure A.2.2.1: Rent

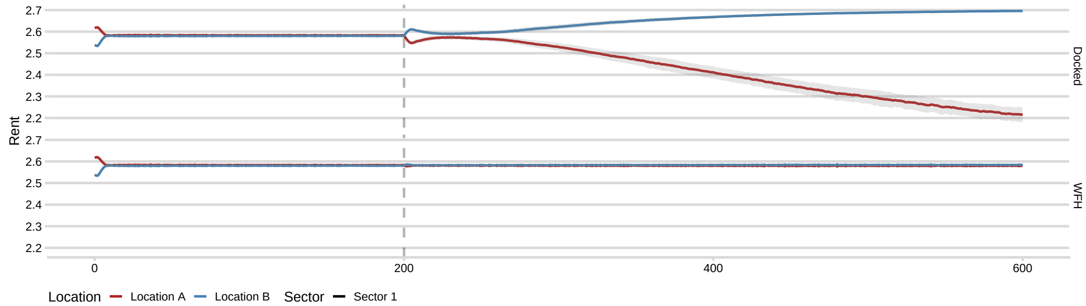


Figure A.2.2.2: Total Firms

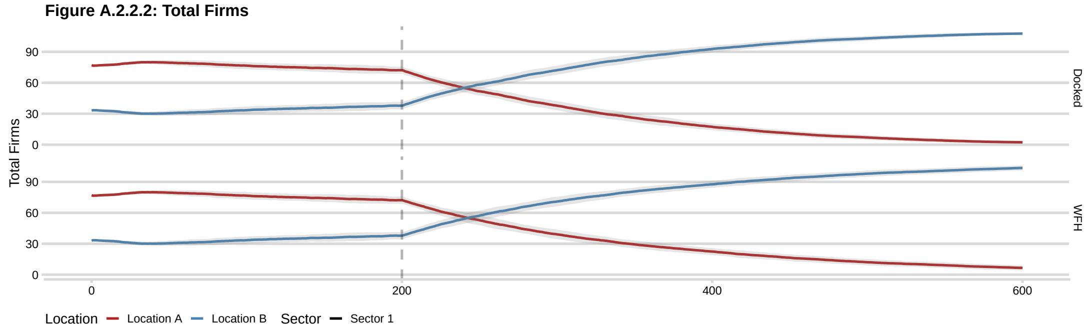


Figure A.2.2.3: Mean Profit

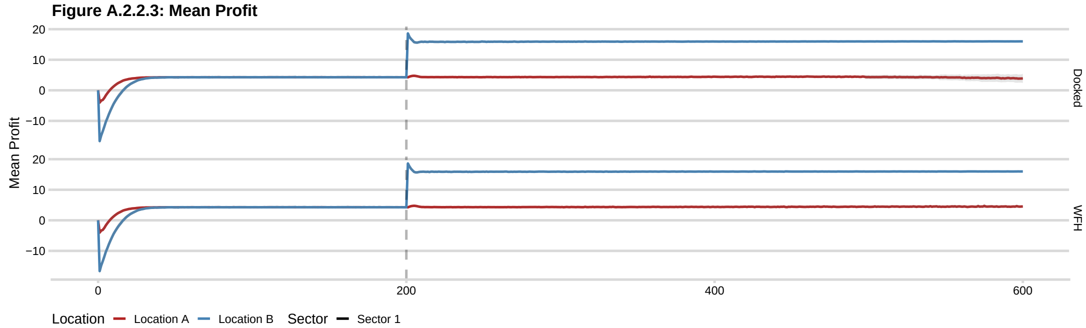


Figure A.2.2.4: Mean Nominal Wage

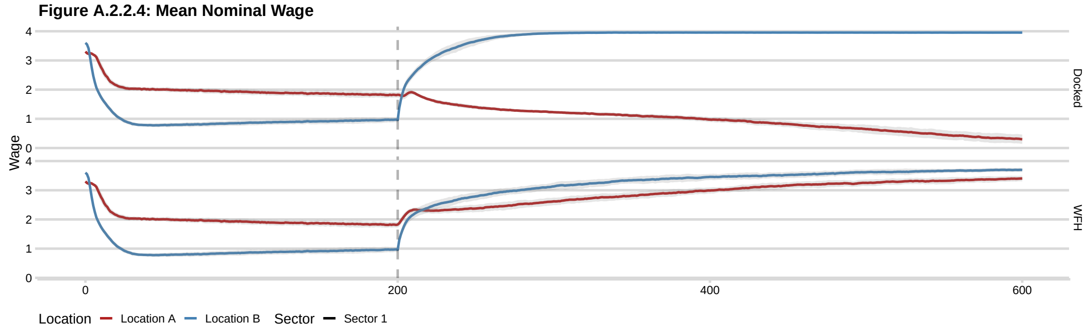


Figure A.2.2.5: Mean Real Wage

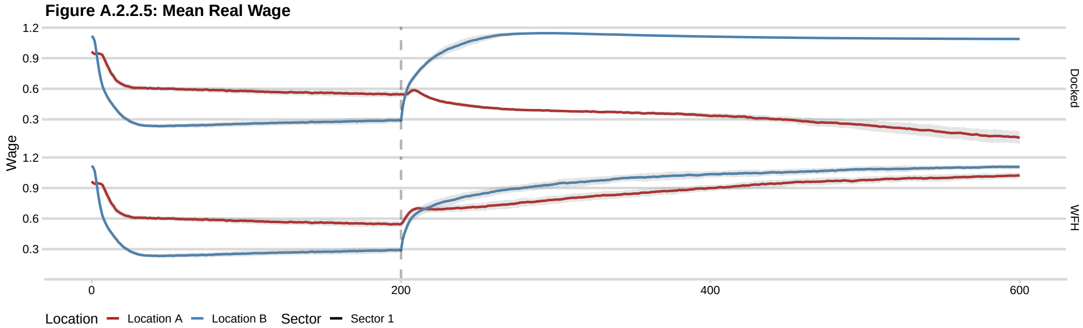


Figure A.2.2.6: Mean Nominal Wage (employed only)

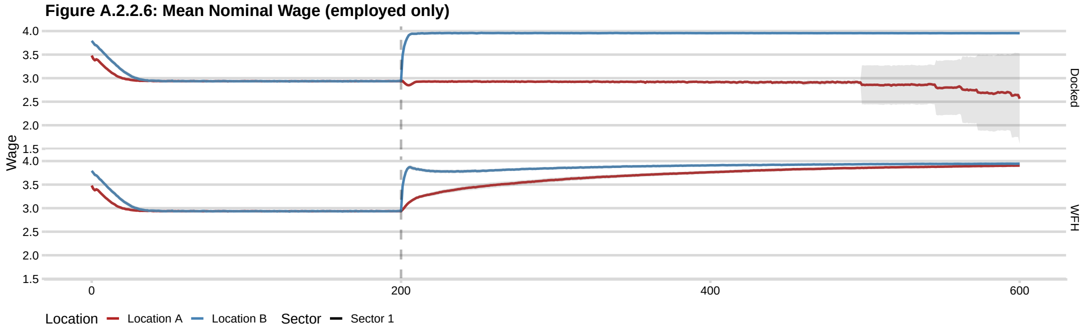


Figure A.2.2.7: Mean Real Wage (employed only)

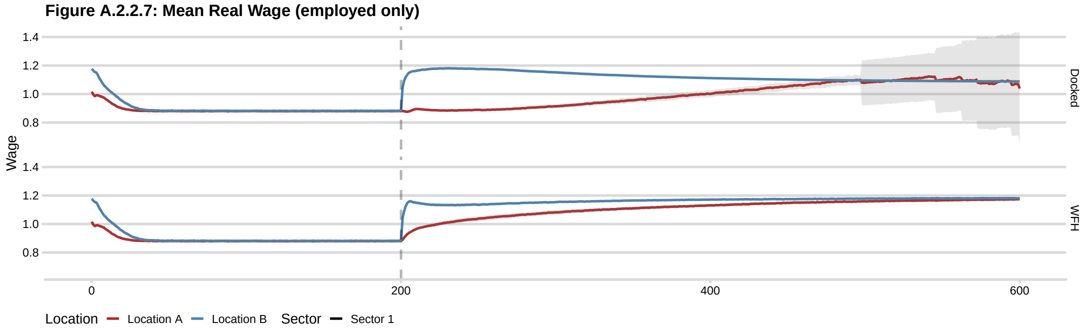


Figure A.2.2.8: Employment Rate

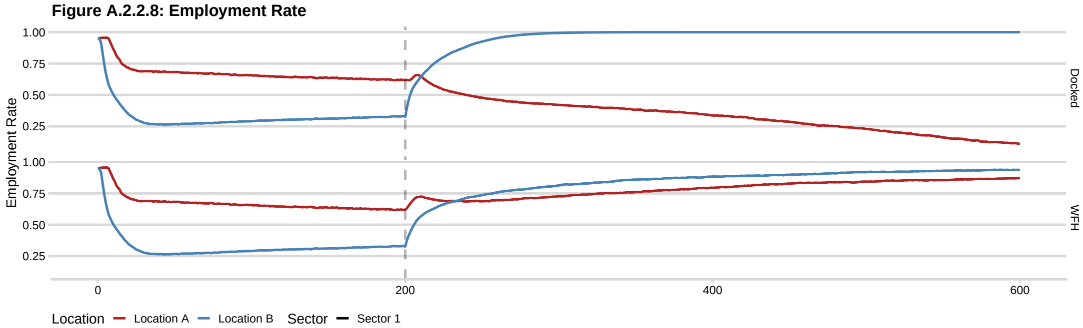
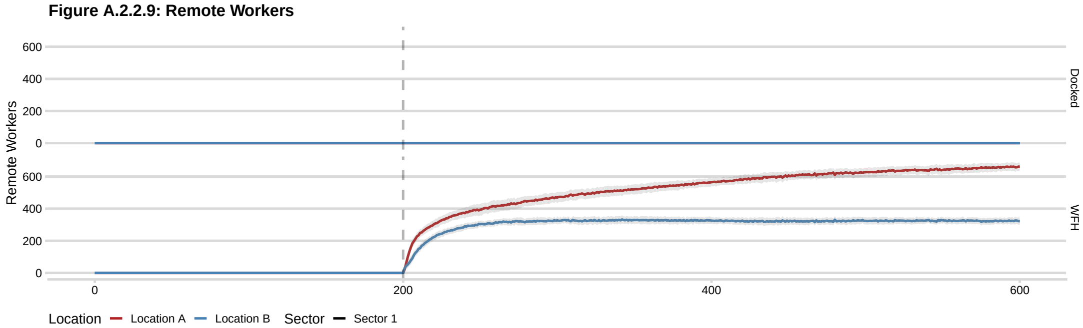


Figure A.2.2.9: Remote Workers



A.2.3 Incidence: No Idiosyncratic Location Preference

Figure A.2.3.1: Rent

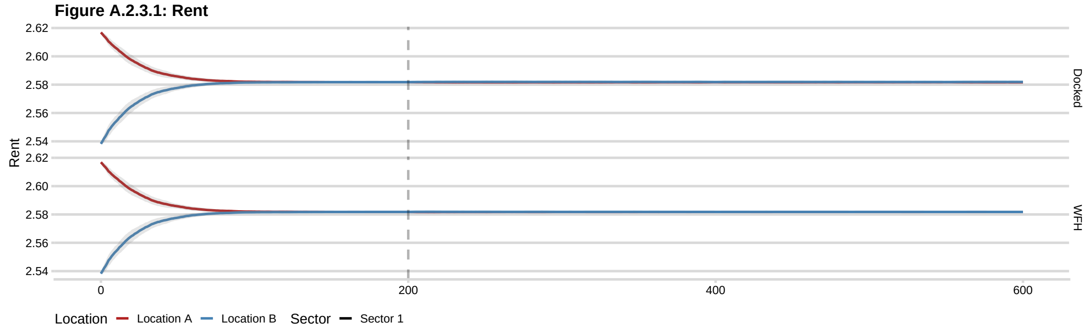


Figure A.2.3.2: Total Firms

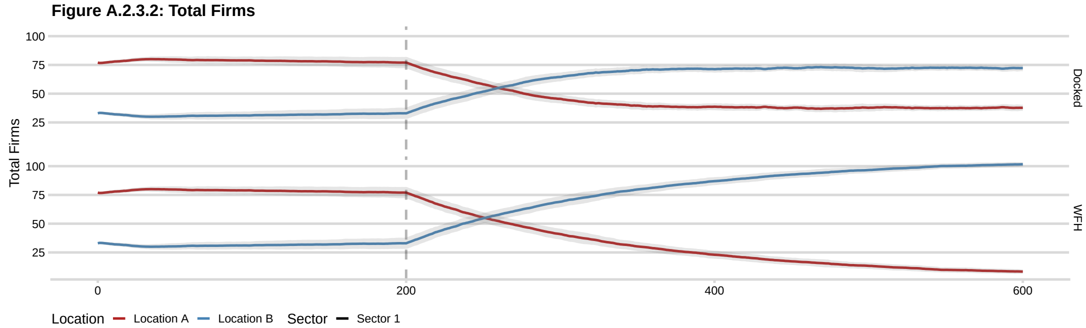


Figure A.2.3.3: Mean Profit

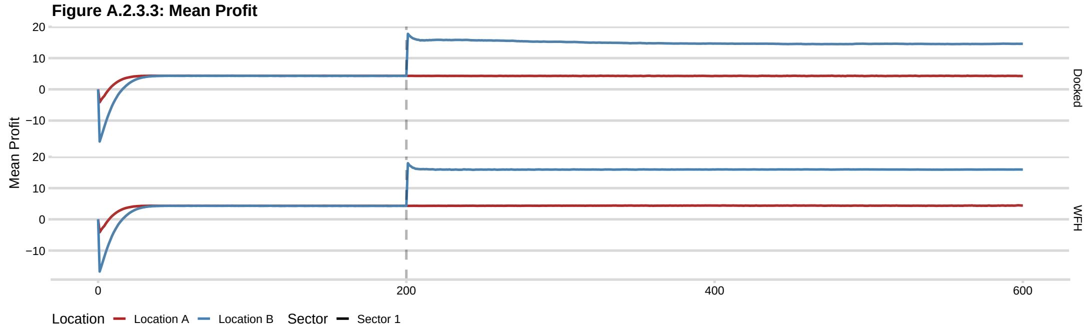


Figure A.2.3.4: Mean Nominal Wage

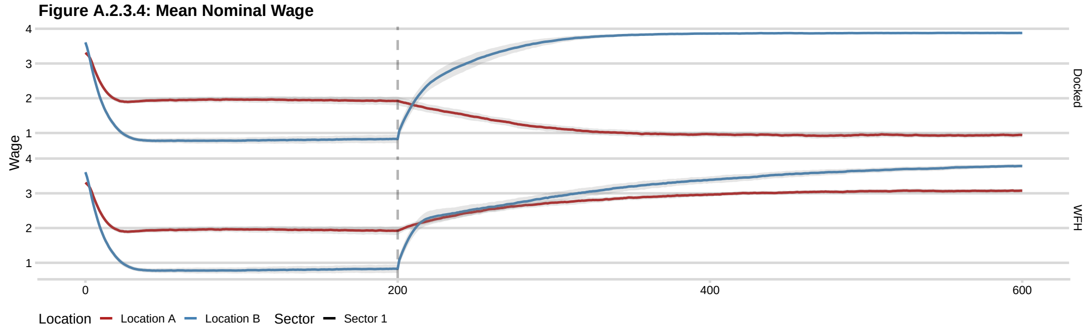


Figure A.2.3.5: Mean Real Wage

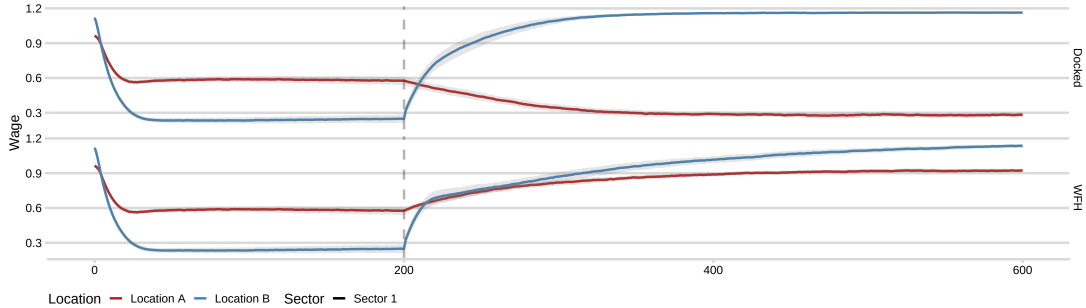


Figure A.2.3.6: Mean Nominal Wage (employed only)

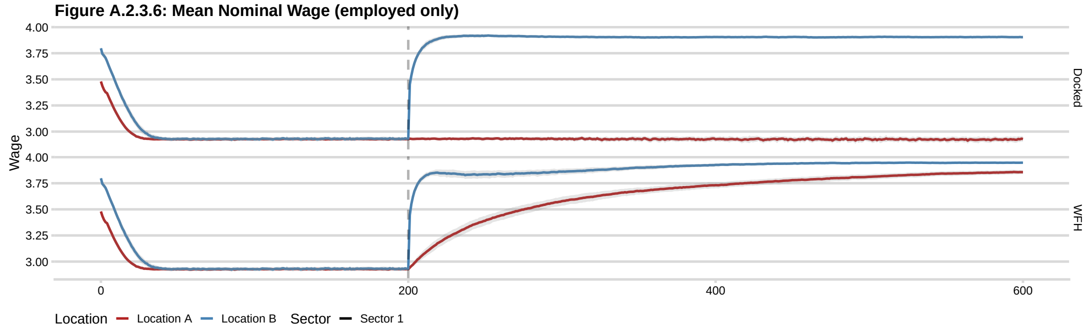


Figure A.2.3.7: Mean Real Wage (employed only)

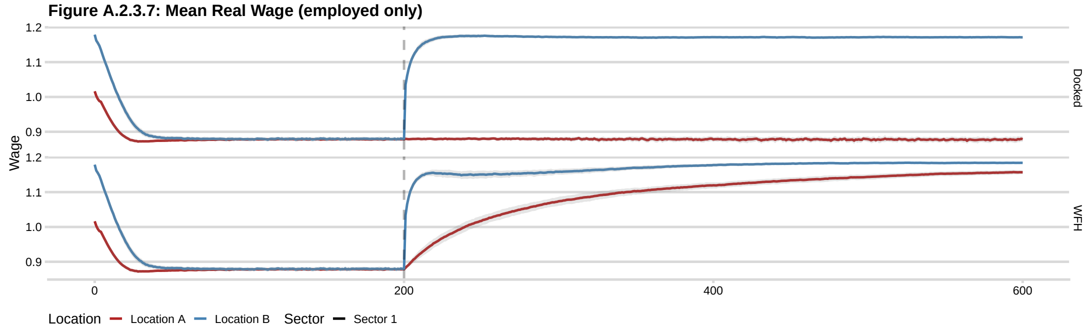


Figure A.2.3.8: Employment Rate

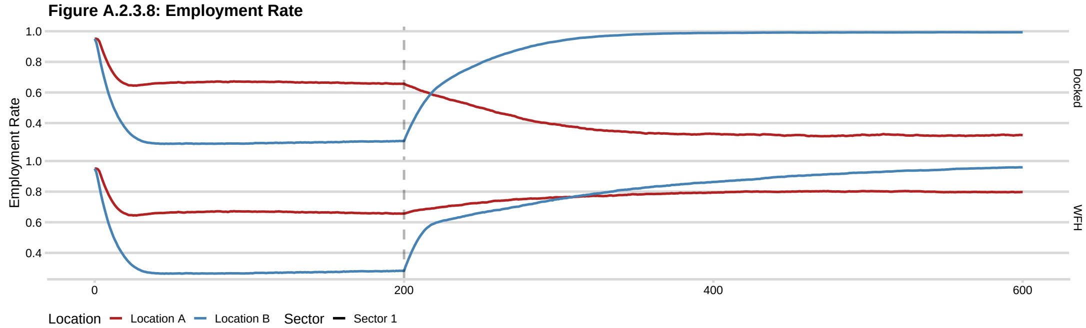
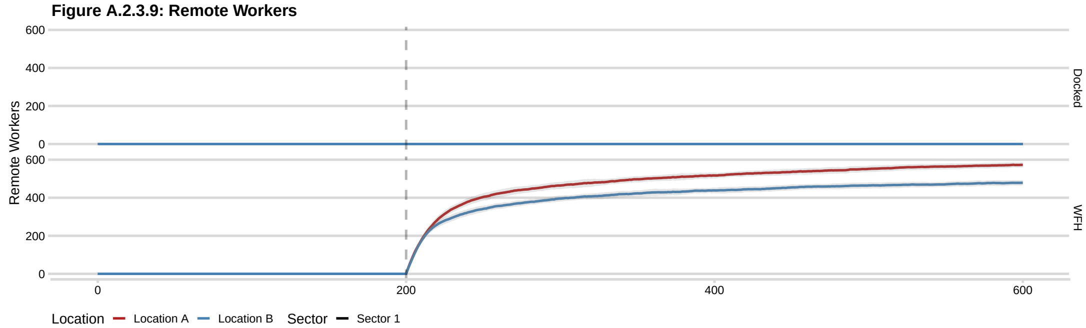


Figure A.2.3.9: Remote Workers



A.2.4 Incidence: No Housing Elasticity

Figure A.2.4.1: Rent

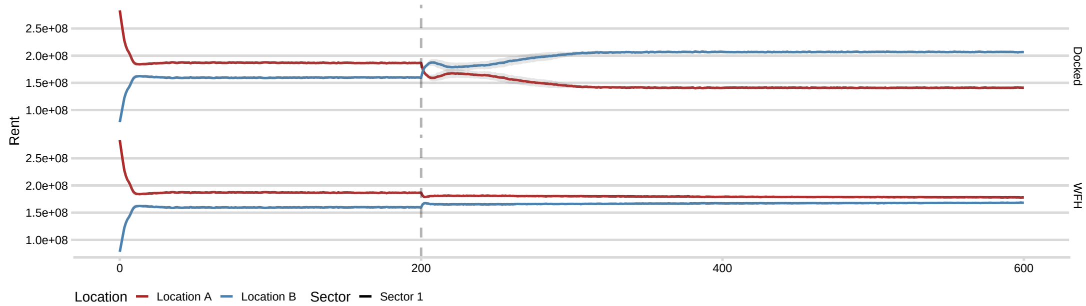


Figure A.2.4.2: Total Firms

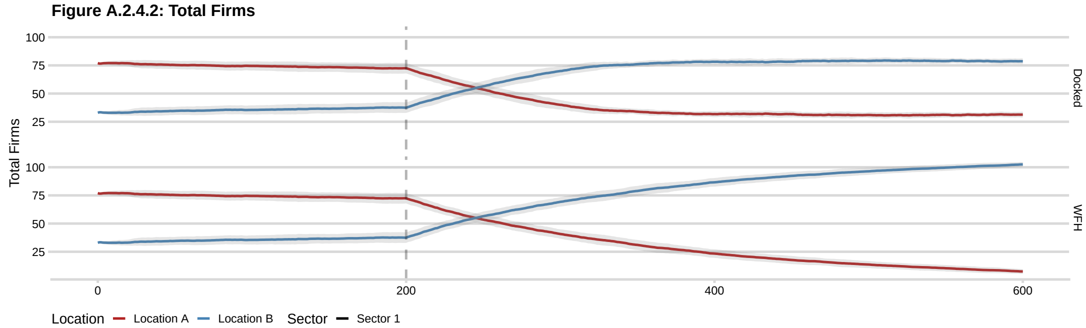


Figure A.2.4.3: Mean Profit

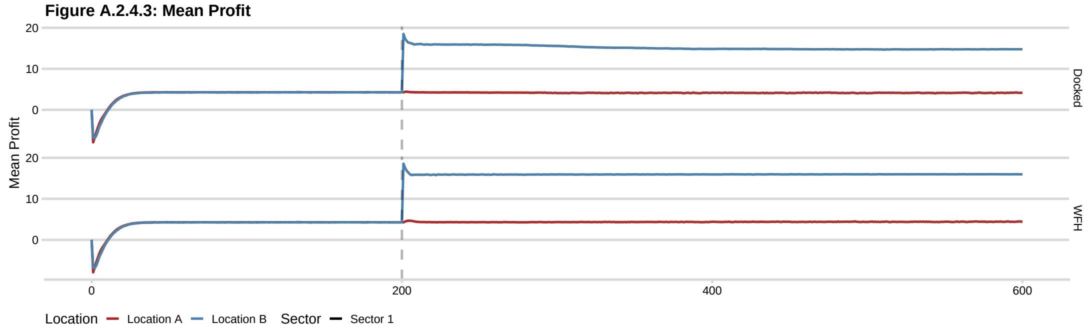


Figure A.2.4.4: Mean Nominal Wage

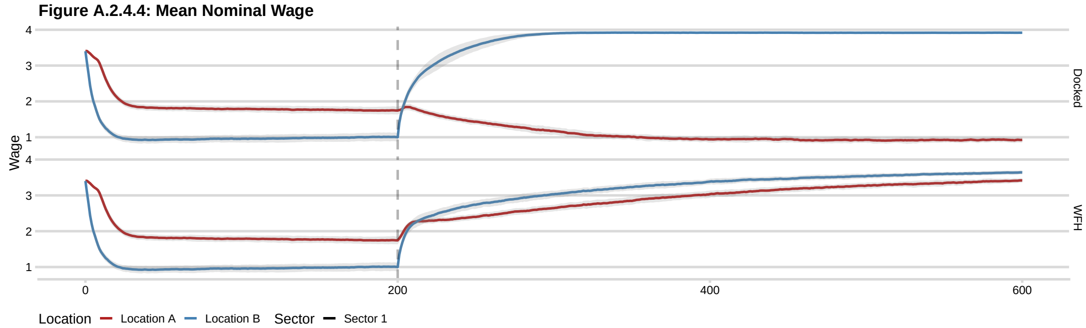


Figure A.2.4.5: Mean Real Wage

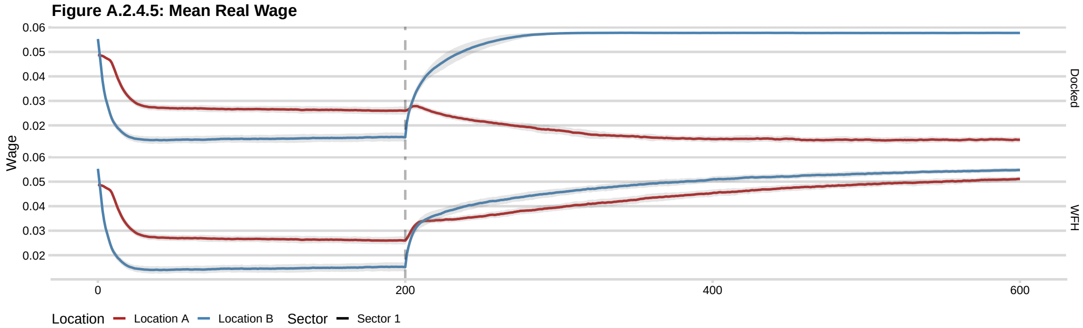


Figure A.2.4.6: Mean Nominal Wage (employed only)

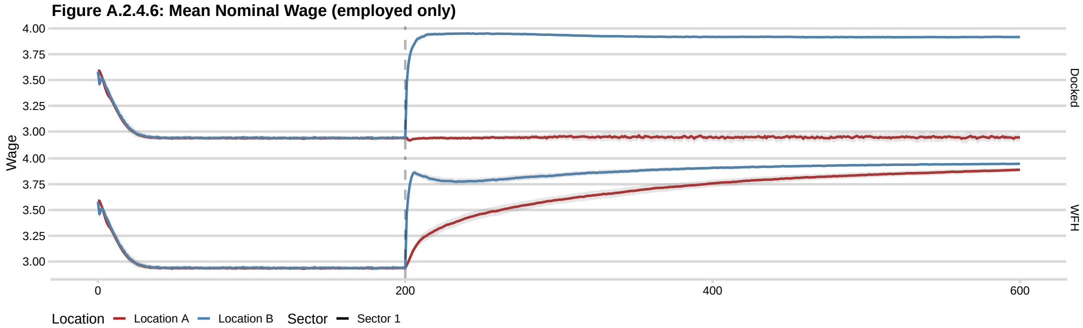


Figure A.2.4.7: Mean Real Wage (employed only)

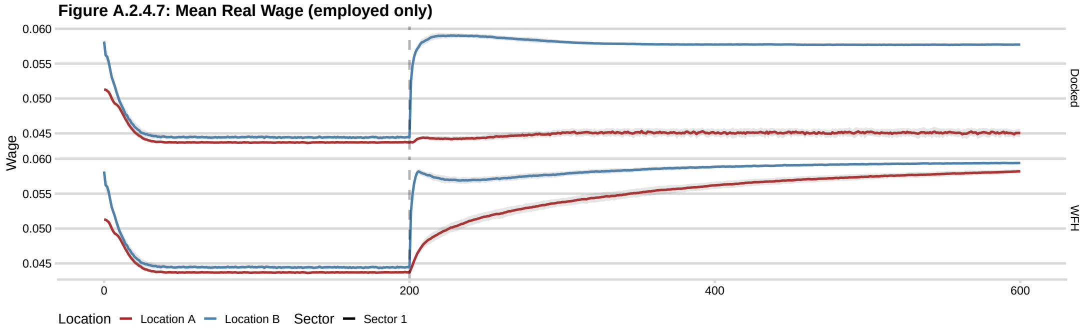


Figure A.2.4.8: Employment Rate

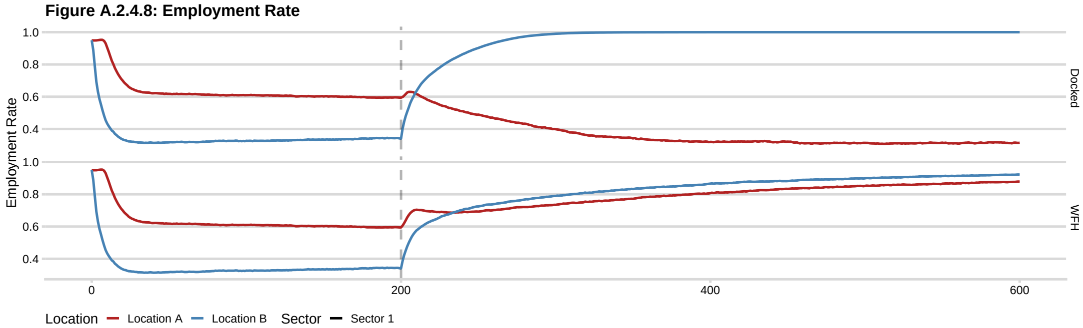
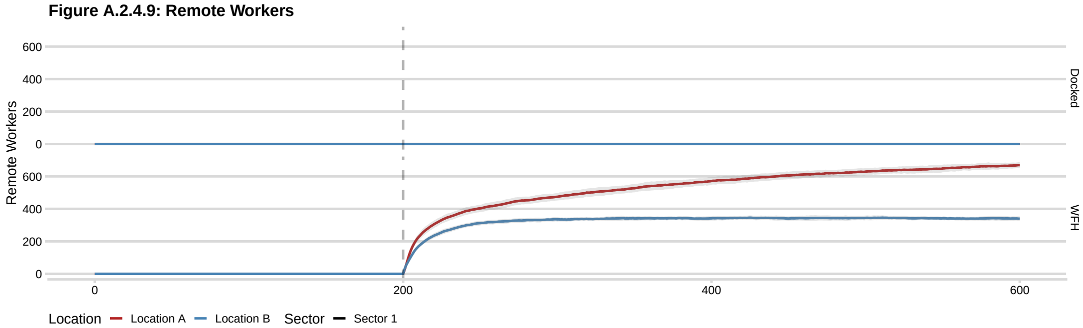
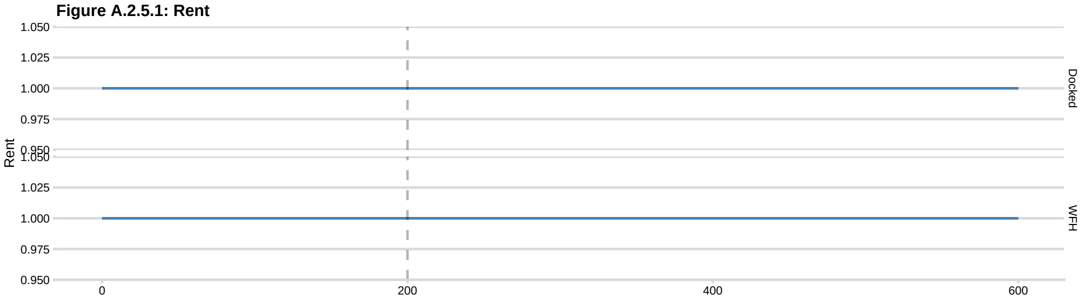


Figure A.2.4.9: Remote Workers



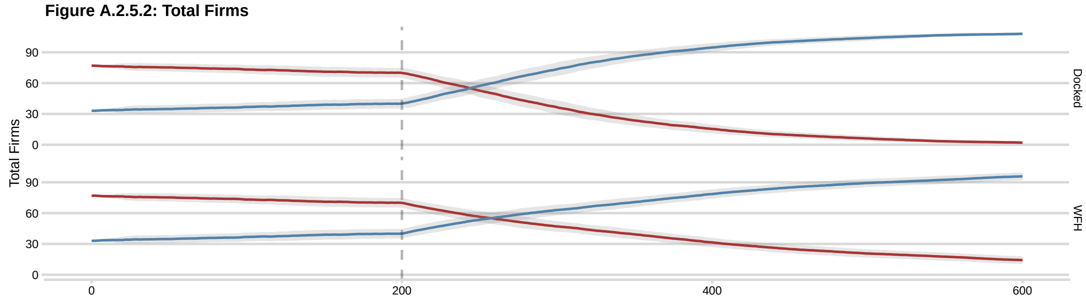
A.2.5 Incidence: Infinite Housing Elasticity

Figure A.2.5.1: Rent



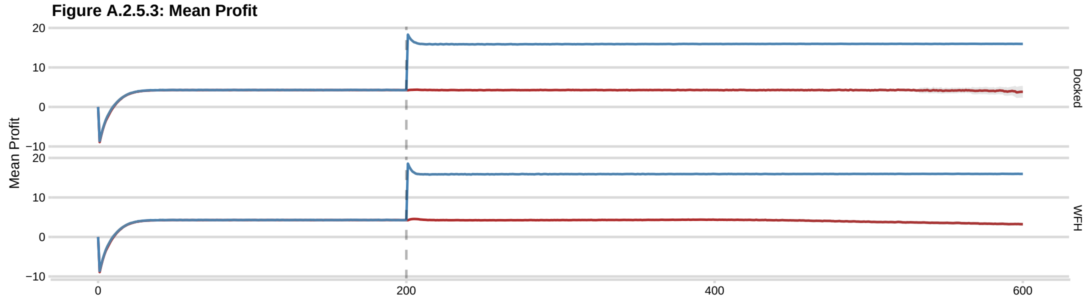
Location — Location A — Location B Sector — Sector 1

Figure A.2.5.2: Total Firms



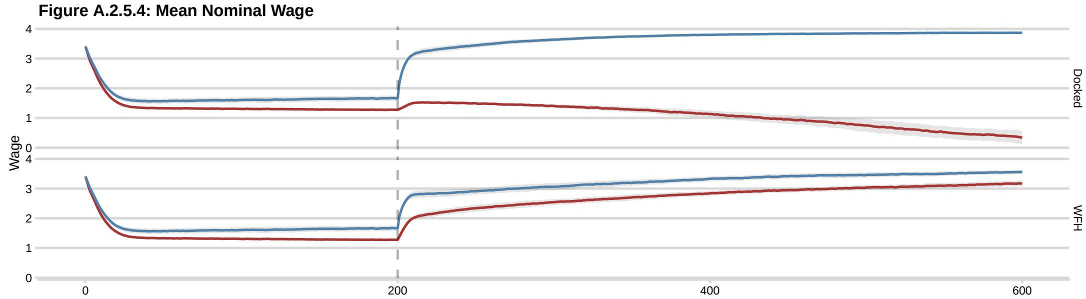
Location — Location A — Location B Sector — Sector 1

Figure A.2.5.3: Mean Profit



Location — Location A — Location B Sector — Sector 1

Figure A.2.5.4: Mean Nominal Wage



Location — Location A — Location B Sector — Sector 1

Figure A.2.5.5: Mean Real Wage

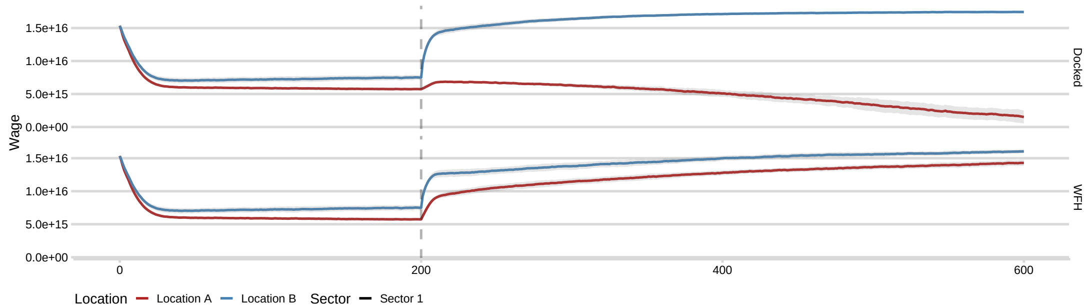


Figure A.2.5.6: Mean Nominal Wage (employed only)

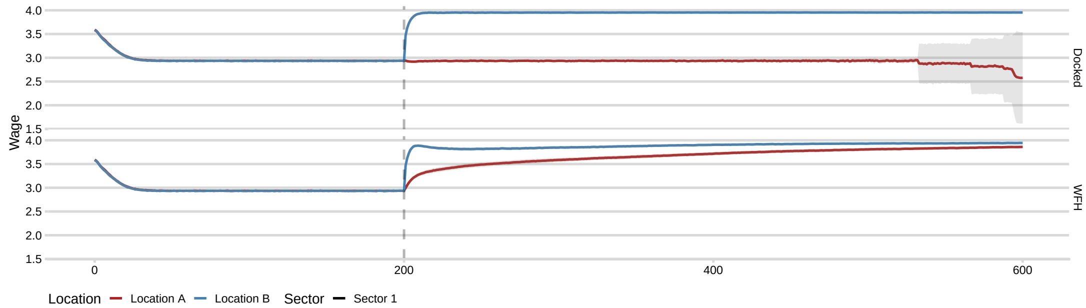


Figure A.2.5.7: Mean Real Wage (employed only)

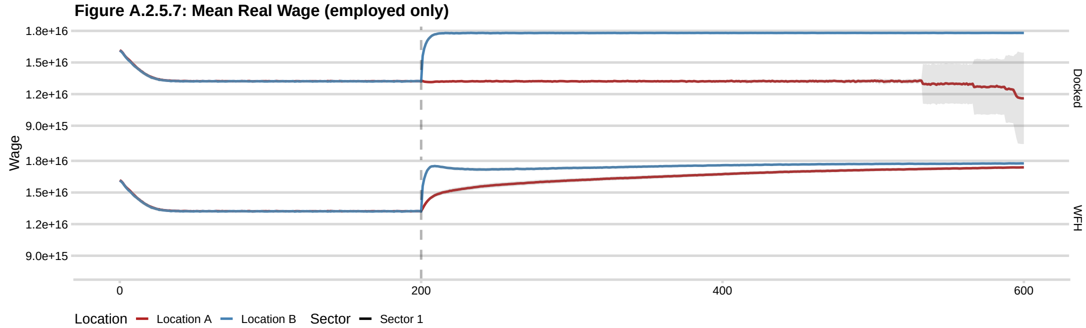


Figure A.2.5.8: Employment Rate

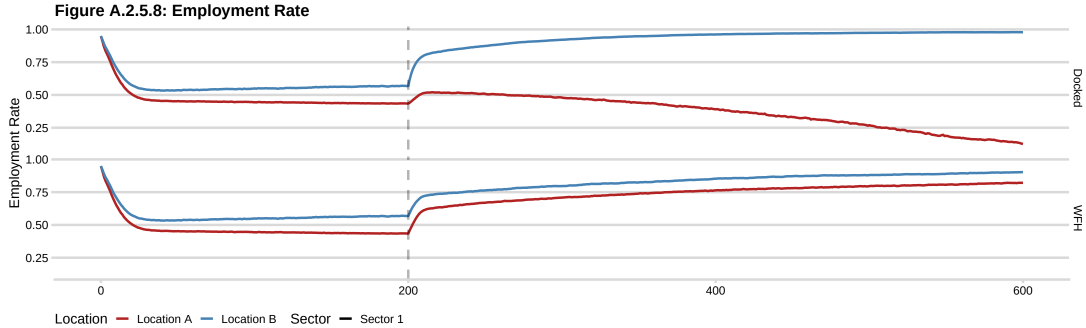
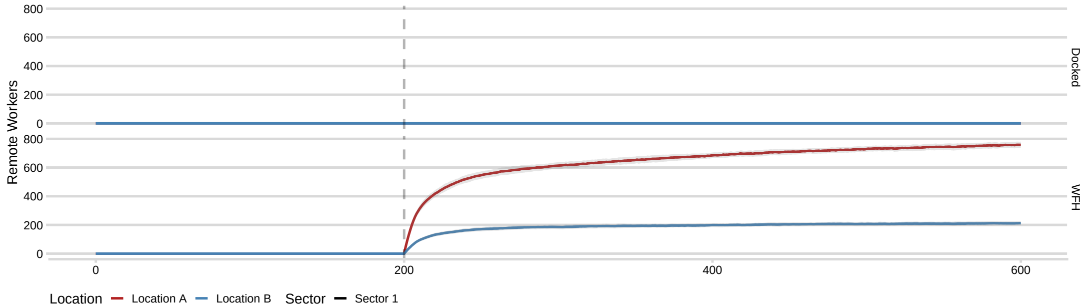


Figure A.2.5.9: Remote Workers



B Appendix B: Heterogeneous Labor

Figures and tables related to heterogeneous labor simulations (sections 4.3 and 5.2) can be found here.

B.1 Tables: WFH vs Docked

The tables below display the equilibrium post-shock values of each metric for both the docked and work from home cases.

Table B.1.1.1: Employment Rate

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	1	1	1	1	1	1	1	1	1	1	1	1
k_{high}	1	1	1	1	1	1	1	1	1	1	1	1
More Unskilled than Skilled												
k_{low}	1	1	1	1	1	1	1	1	1	1	1	1
k_{high}	1	1	1	1	1	1	1	1	1	1	1	1

Table B.1.1.2: Employed

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	171.56	413.54	2.41	593.48	533.34	0.90	613.44	371.46	0.61	191.32	251.54	1.31
k_{high}	174.48	374.62	2.15	599.42	484.44	0.81	610.48	410.38	0.67	185.40	300.52	1.62
More Unskilled than Skilled												
k_{low}	60.00	234.52	3.91	785.64	732.74	0.93	410.98	236.48	0.58	313.22	366.04	1.17
k_{high}	45.54	211.14	4.64	765.52	659.20	0.86	425.46	259.86	0.61	333.28	439.72	1.32

Table B.1.1.3: Total

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	171.56	413.54	2.41	593.68	533.44	0.90	613.44	371.46	0.61	191.32	251.56	1.31
k_{high}	174.52	374.62	2.15	599.60	484.48	0.81	610.48	410.38	0.67	185.40	300.52	1.62
More Unskilled than Skilled												
k_{low}	60.02	234.52	3.91	785.76	732.90	0.93	410.98	236.48	0.58	313.24	366.10	1.17
k_{high}	45.54	211.14	4.64	765.68	659.28	0.86	425.46	259.86	0.61	333.32	439.72	1.32

Table B.1.1.4: Real Wage

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	1.44	1.59	1.10	1.44	1.40	0.97	1.63	1.70	1.04	1.43	1.49	1.04
k_{high}	0.36	0.40	1.12	0.36	0.36	0.99	0.41	0.42	1.02	0.36	0.36	1.02
More Unskilled than Skilled												
k_{low}	1.16	1.59	1.37	1.42	1.39	0.98	1.66	1.71	1.03	1.46	1.50	1.03
k_{high}	0.30	0.40	1.36	0.36	0.35	0.99	0.41	0.42	1.01	0.36	0.37	1.01

Table B.1.1.5: Nominal Wage

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	4.79	5.44	1.14	4.80	4.79	1	5.46	5.47	1	4.78	4.79	1
k_{high}	4.80	5.46	1.14	4.80	4.80	1	5.46	5.46	1	4.77	4.78	1
More Unskilled than Skilled												
k_{low}	3.91	5.45	1.39	4.79	4.79	1	5.46	5.47	1	4.79	4.80	1
k_{high}	3.96	5.45	1.38	4.79	4.80	1	5.46	5.47	1	4.79	4.79	1

Table B.1.1.6: Employed Real Wage

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	1.44	1.59	1.10	1.44	1.40	0.97	1.63	1.70	1.04	1.43	1.49	1.04
k_{high}	0.36	0.40	1.12	0.36	0.36	0.99	0.41	0.42	1.02	0.36	0.36	1.02
More Unskilled than Skilled												
k_{low}	1.16	1.59	1.37	1.42	1.39	0.98	1.66	1.71	1.03	1.46	1.50	1.03
k_{high}	0.30	0.40	1.36	0.36	0.35	0.99	0.41	0.42	1.01	0.36	0.37	1.01

Table B.1.1.7: Employed Nominal Wage

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	4.79	5.44	1.14	4.80	4.79	1	5.46	5.47	1	4.78	4.79	1
k_{high}	4.80	5.46	1.14	4.80	4.80	1	5.46	5.46	1	4.77	4.78	1
More Unskilled than Skilled												
k_{low}	3.92	5.45	1.39	4.79	4.79	1	5.46	5.47	1	4.79	4.80	1
k_{high}	3.96	5.45	1.38	4.80	4.80	1	5.46	5.47	1	4.79	4.79	1

Table B.1.1.8: Remote Workers

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	0	387.46	Inf	0	4.76	Inf	0	136.82	Inf	0	2.60	Inf
k_{high}	0	356.80	Inf	0	4.02	Inf	0	160.34	Inf	0	2.68	Inf
More Unskilled than Skilled												
k_{low}	0	223.50	Inf	0	5.52	Inf	0	84.98	Inf	0	2.38	Inf
k_{high}	0	202.44	Inf	0	5.82	Inf	0	101.60	Inf	0	3.32	Inf

Table B.1.1.9: Preferred Location

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	171.40	413.54	2.41	583.42	531.14	0.91	198.42	198.58	1	184.06	192.02	1.04
k_{high}	174.36	374.60	2.15	579.50	483.54	0.83	198.42	198.56	1	174.22	193.38	1.11
More Unskilled than Skilled												
k_{low}	59.88	234.52	3.92	783.18	730.12	0.93	118.60	118.74	1	271.58	271.38	1.00
k_{high}	45.40	211.14	4.65	763.24	657.92	0.86	118.60	118.74	1	271.72	272.80	1.00

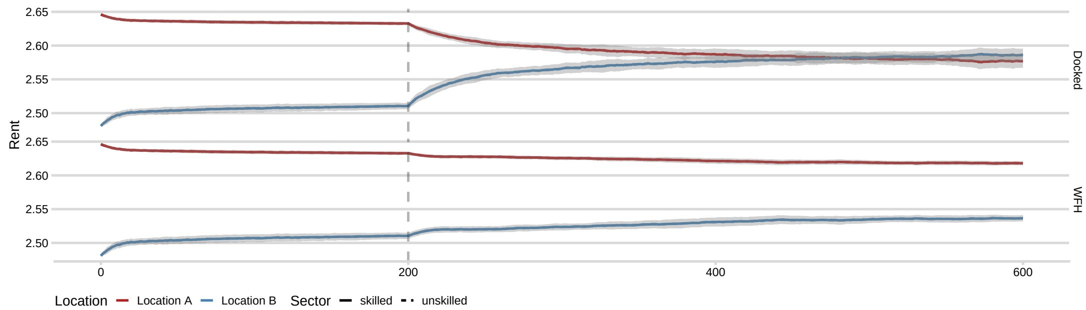
Table B.1.1.10: Preferred Location Rate

	Location A						Location B					
	Skilled			unSkilled			Skilled			unSkilled		
	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio	Docked	WFH	Ratio
Even Skilled/Unskilled												
k_{low}	1	1	1	0.98	1	1.01	0.32	0.53	1.65	0.96	0.76	0.79
k_{high}	1	1	1	0.97	1	1.03	0.33	0.48	1.49	0.94	0.64	0.68
More Unskilled than Skilled												
k_{low}	1	1	1	1.00	1	1.00	0.29	0.50	1.74	0.87	0.74	0.85
k_{high}	1	1	1	1.00	1	1.00	0.28	0.46	1.64	0.82	0.62	0.76

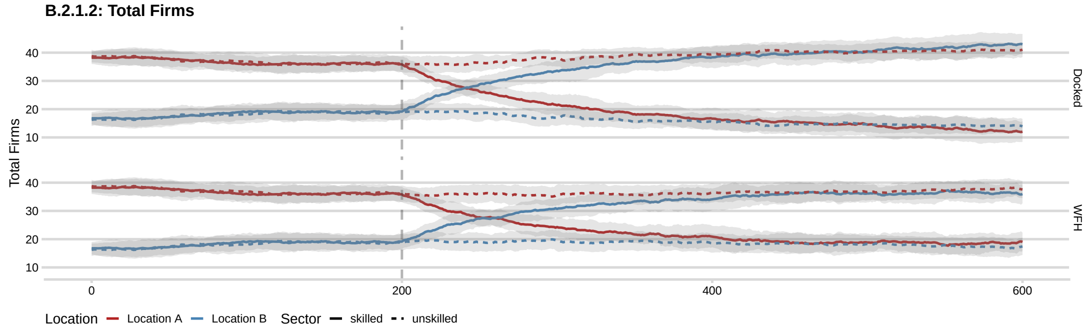
B.2 Plots: Heterogenous Labor

B.2.1 High Housing Elasticity, Even Sector Ratio

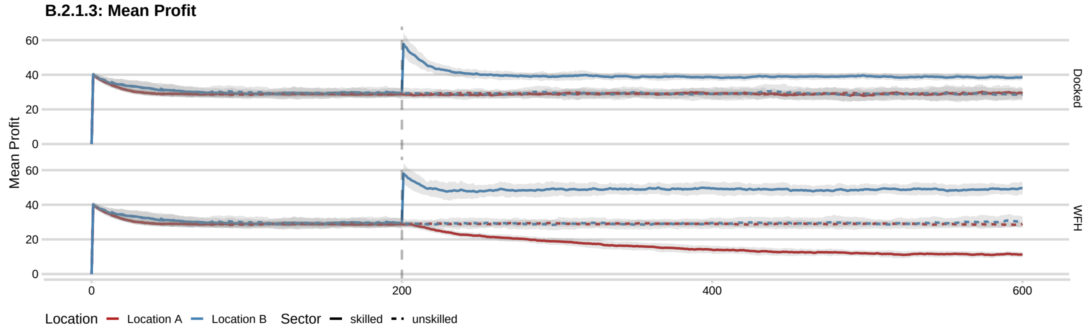
B.2.1.1: Rent



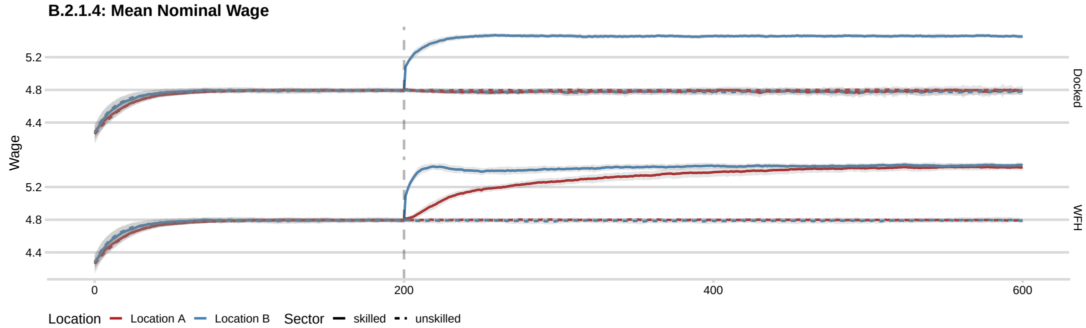
B.2.1.2: Total Firms



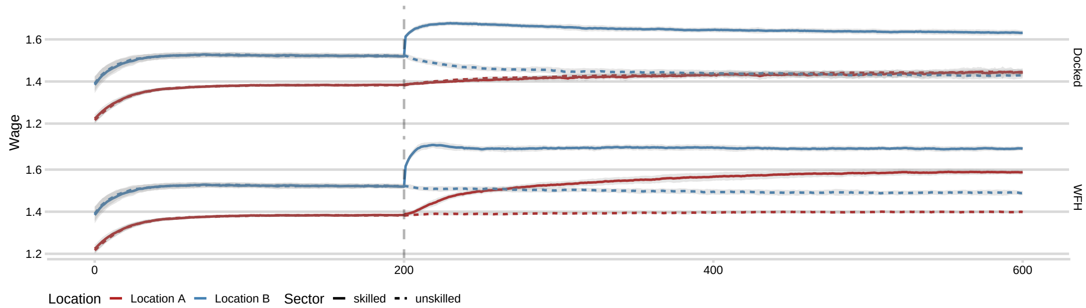
B.2.1.3: Mean Profit



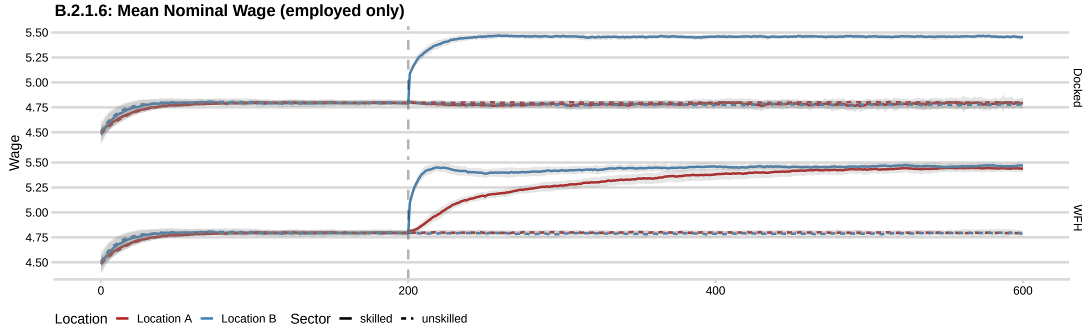
B.2.1.4: Mean Nominal Wage



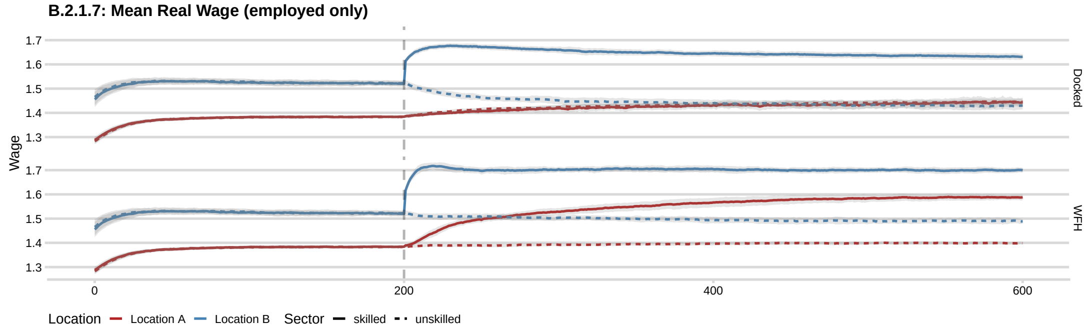
B.2.1.5: Mean Real Wage



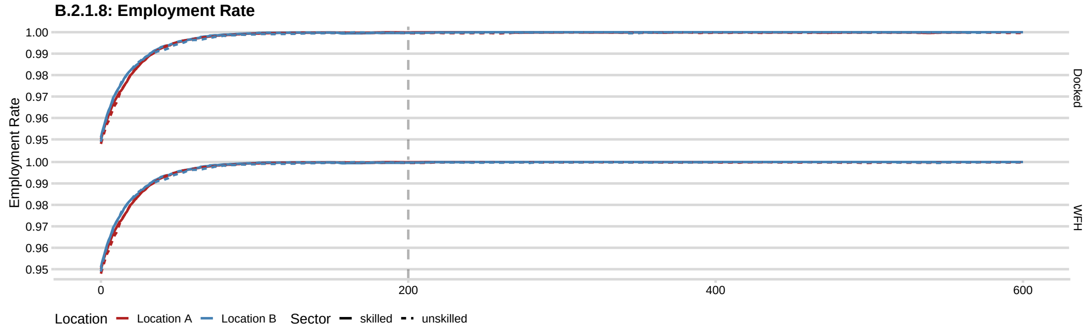
B.2.1.6: Mean Nominal Wage (employed only)



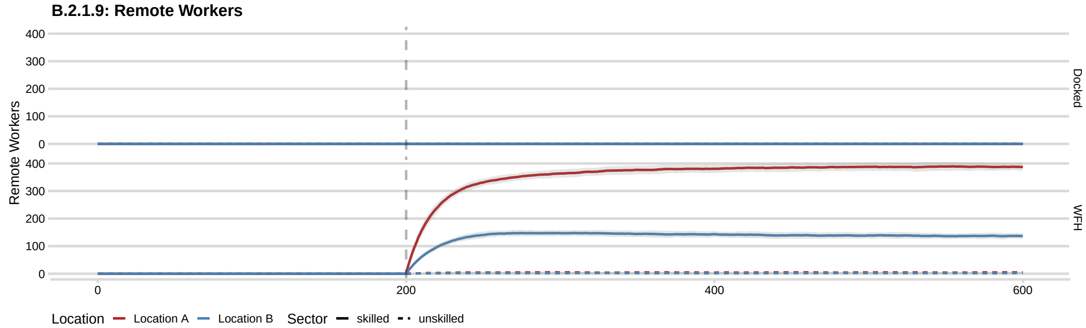
B.2.1.7: Mean Real Wage (employed only)



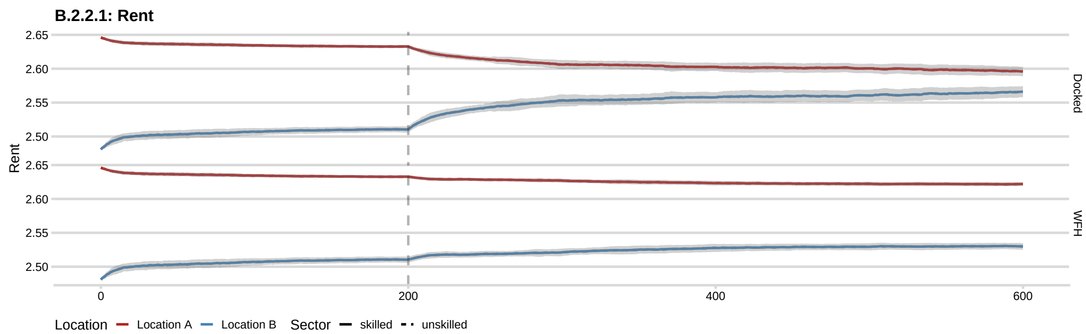
B.2.1.8: Employment Rate

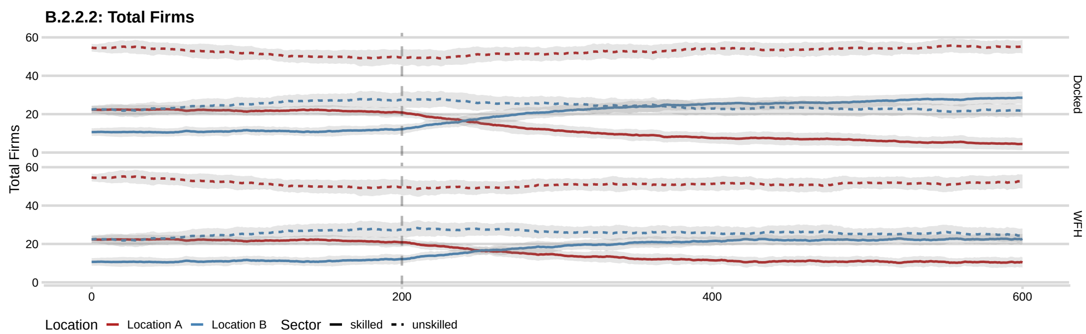


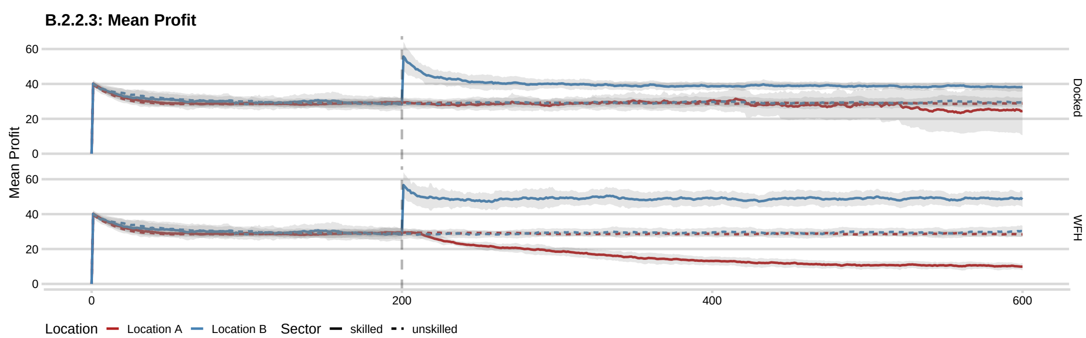
B.2.1.9: Remote Workers

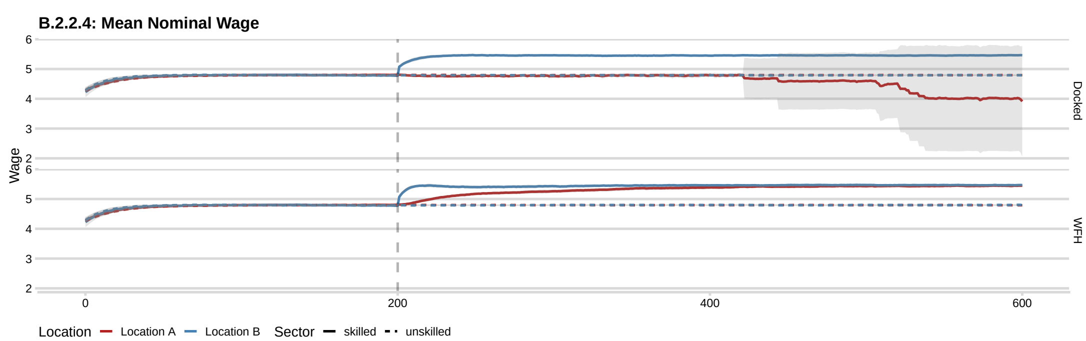


B.2.2 High Housing Elasticity, Uneven Sector Ratio

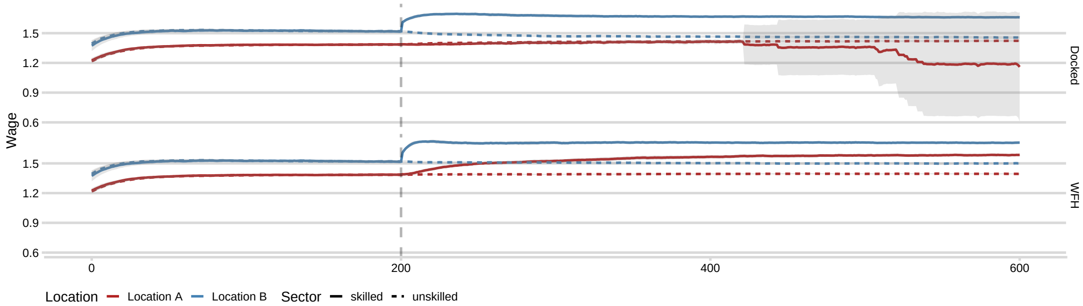




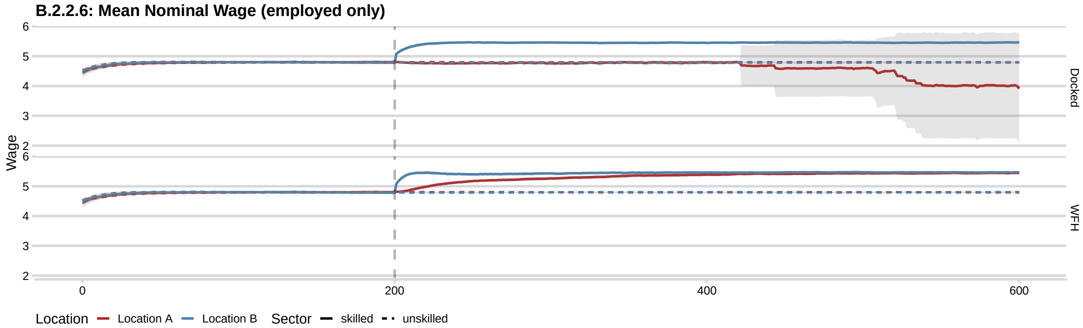




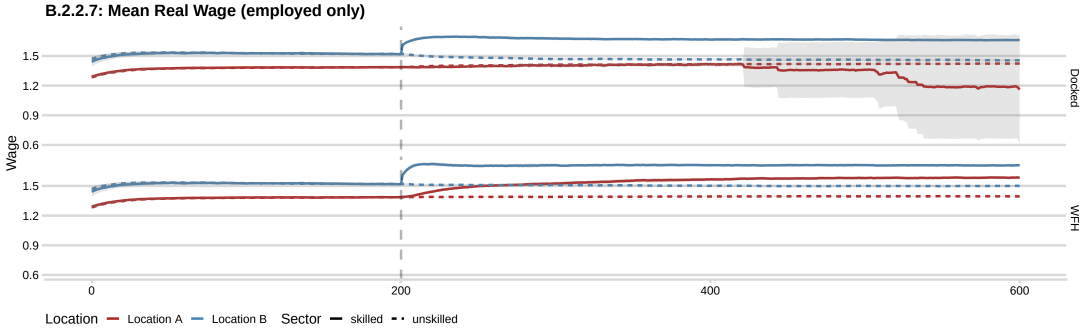
B.2.2.5: Mean Real Wage



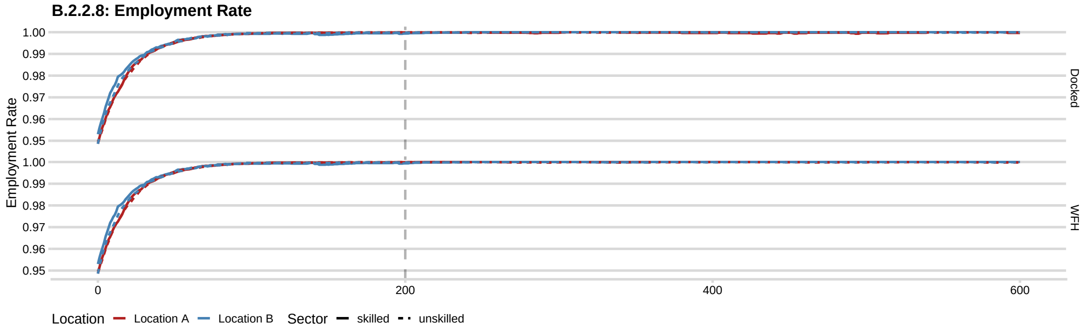
B.2.2.6: Mean Nominal Wage (employed only)



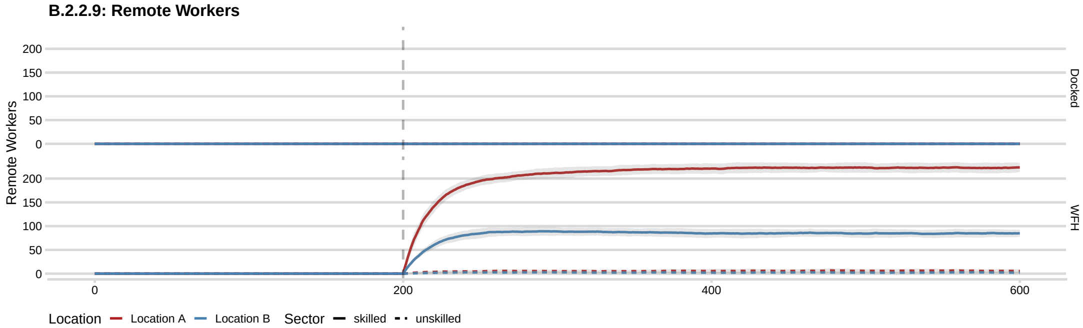
B.2.2.7: Mean Real Wage (employed only)



B.2.2.8: Employment Rate

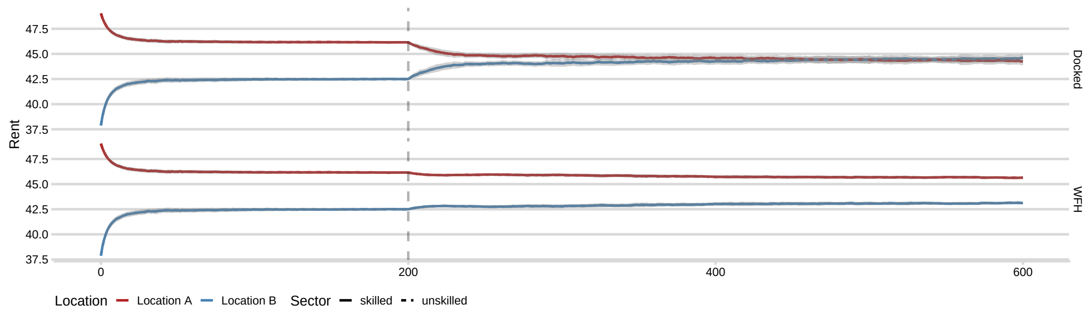


B.2.2.9: Remote Workers

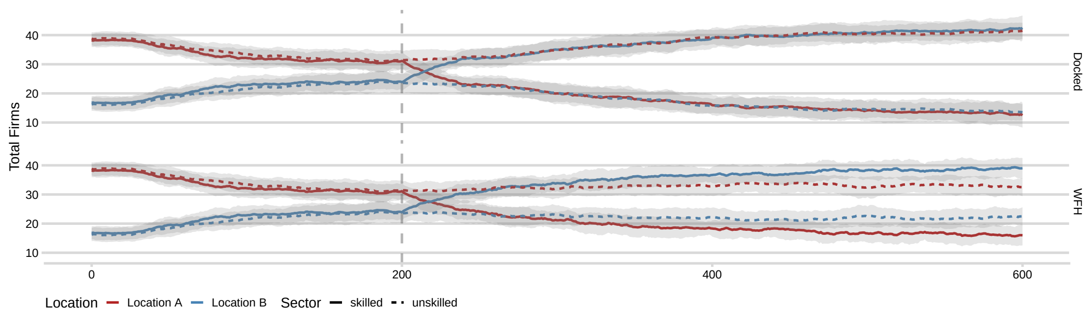


B.2.3 Low Housing Elasticity, Even Sector Ratio

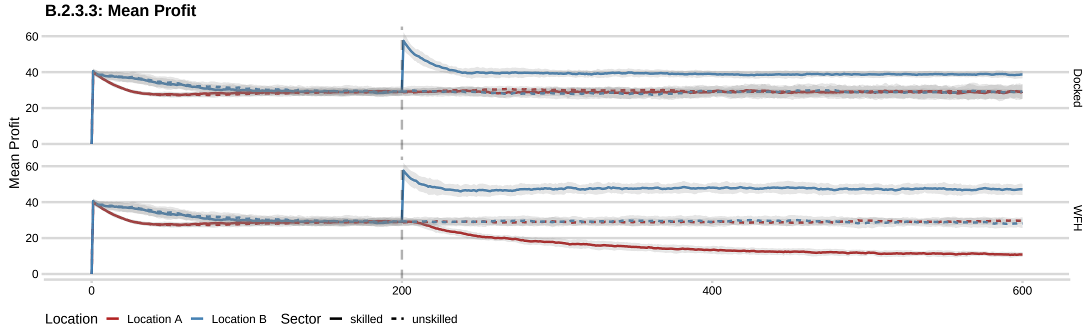
B.2.3.1: Rent



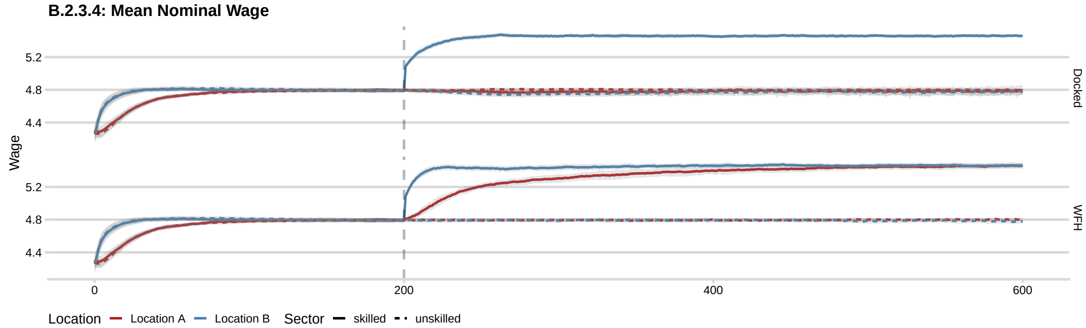
B.2.3.2: Total Firms



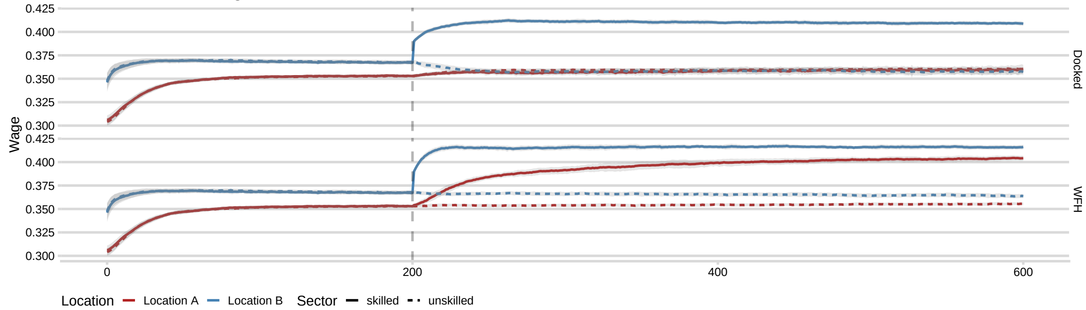
B.2.3.3: Mean Profit



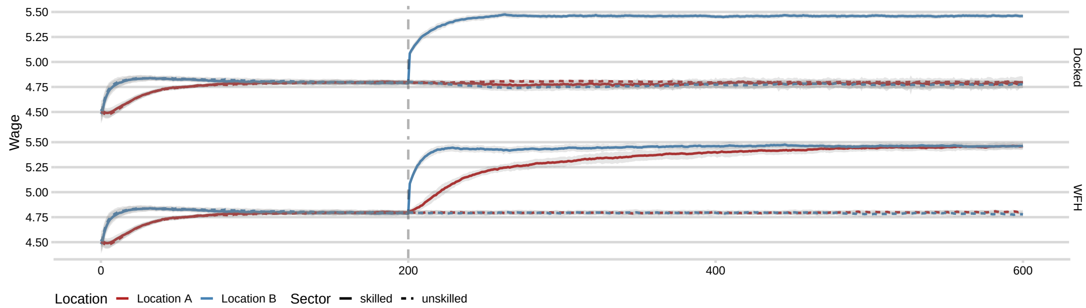
B.2.3.4: Mean Nominal Wage



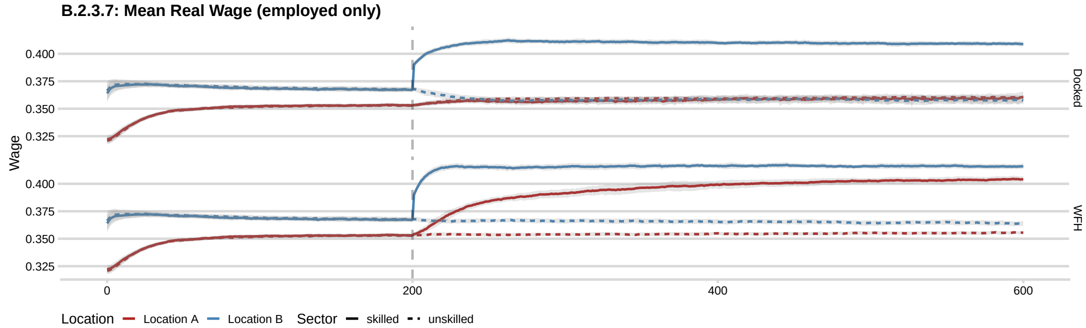
B.2.3.5: Mean Real Wage



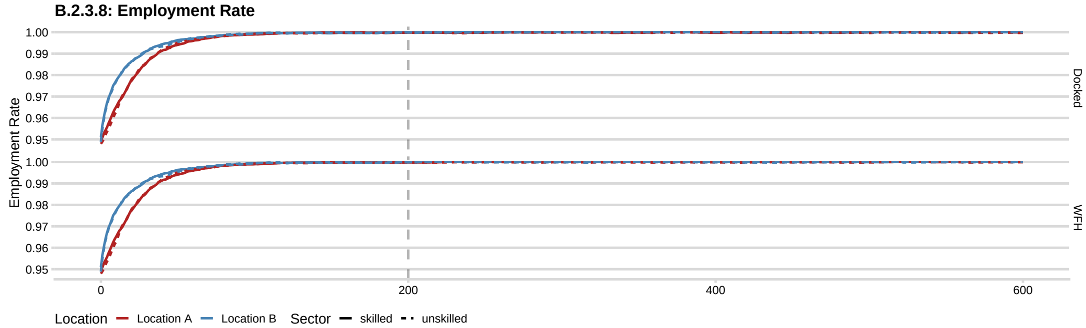
B.2.3.6: Mean Nominal Wage (employed only)



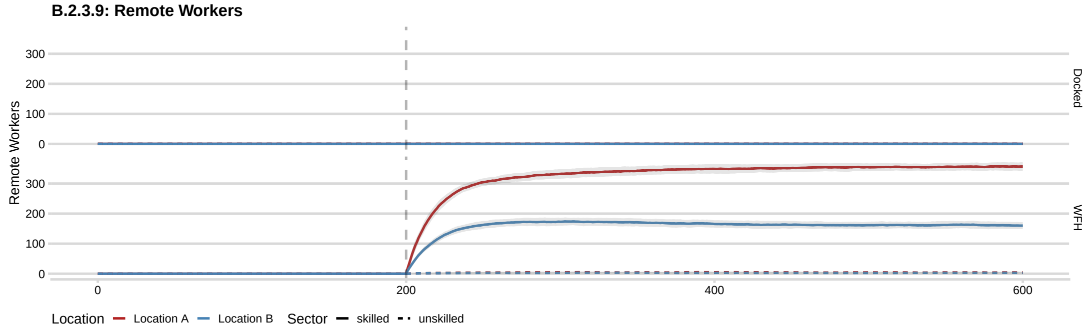
B.2.3.7: Mean Real Wage (employed only)



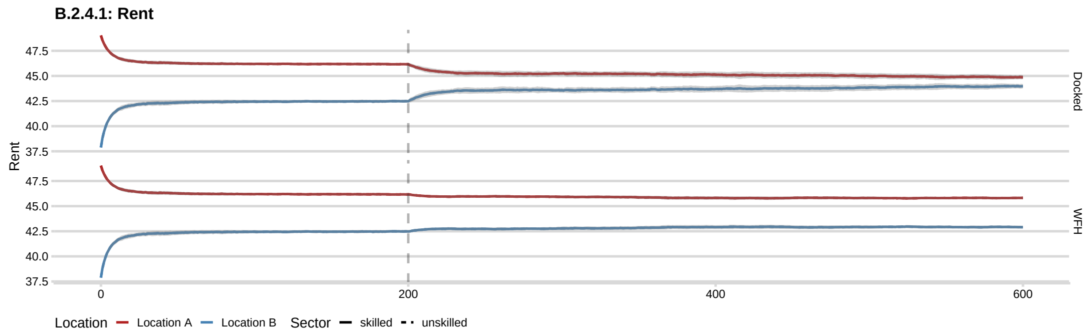
B.2.3.8: Employment Rate

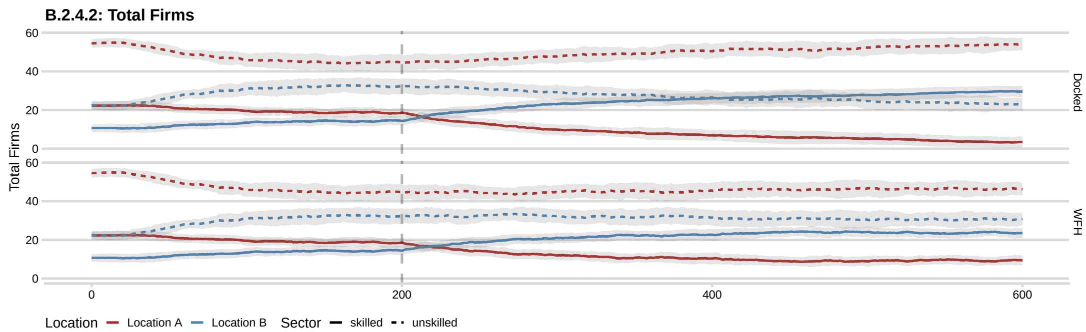


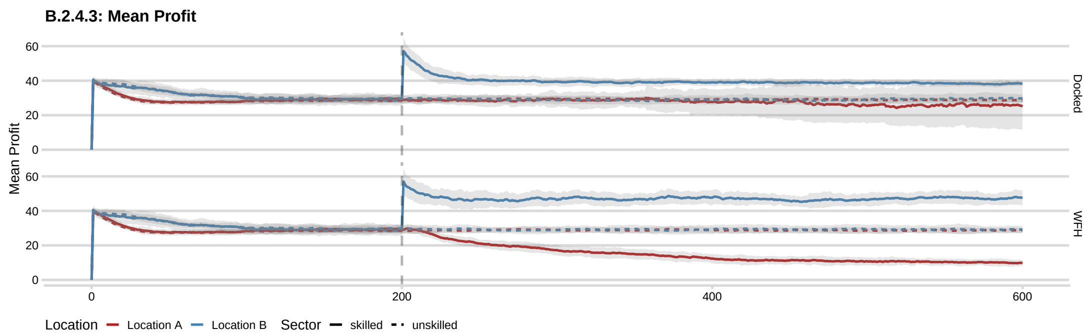
B.2.3.9: Remote Workers

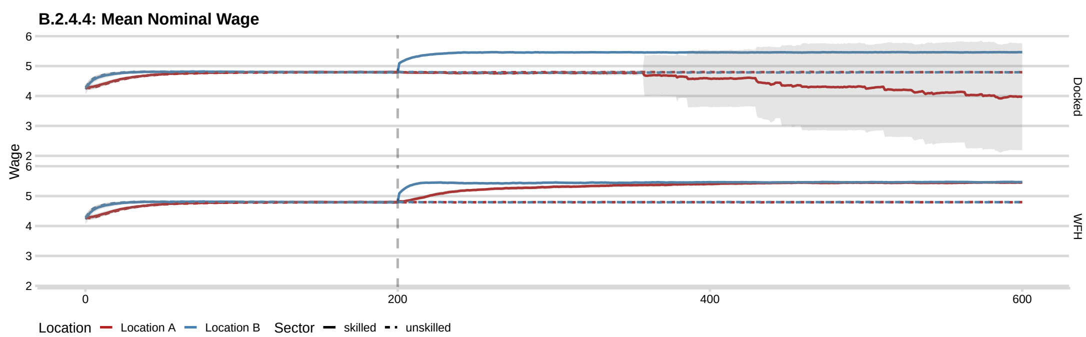


B.2.4 Low Housing Elasticity, Uneven Sector Ratio

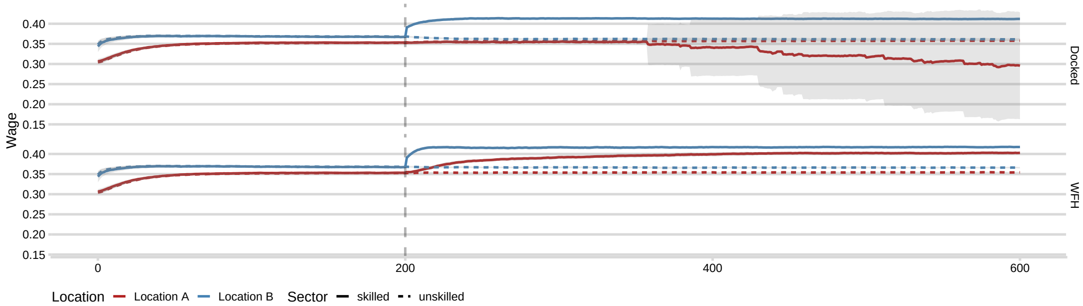




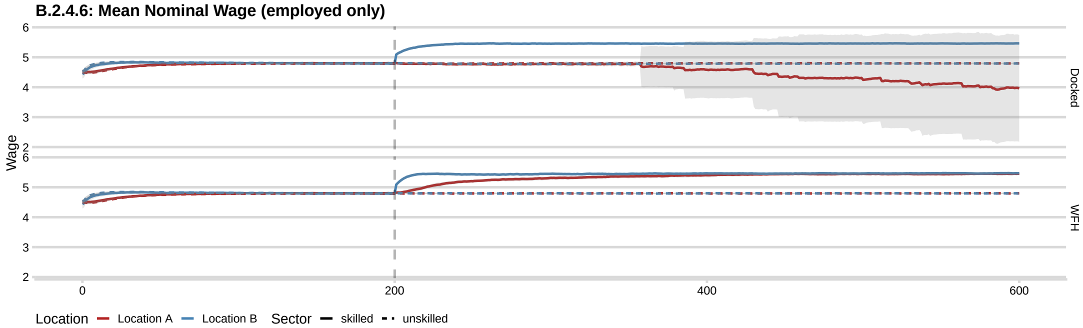




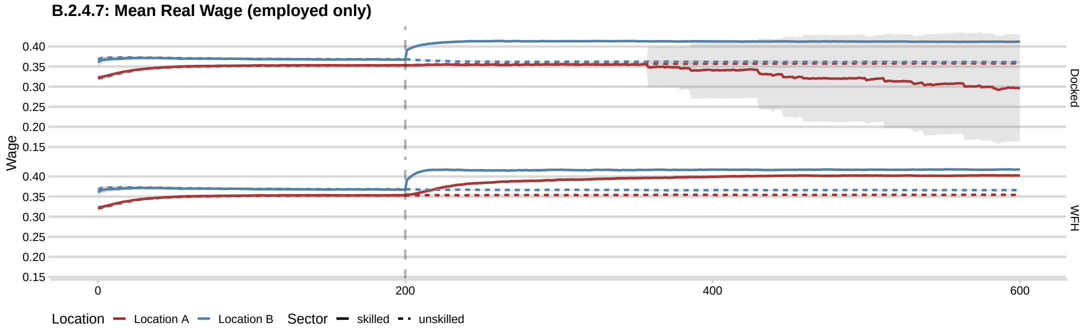
B.2.4.5: Mean Real Wage



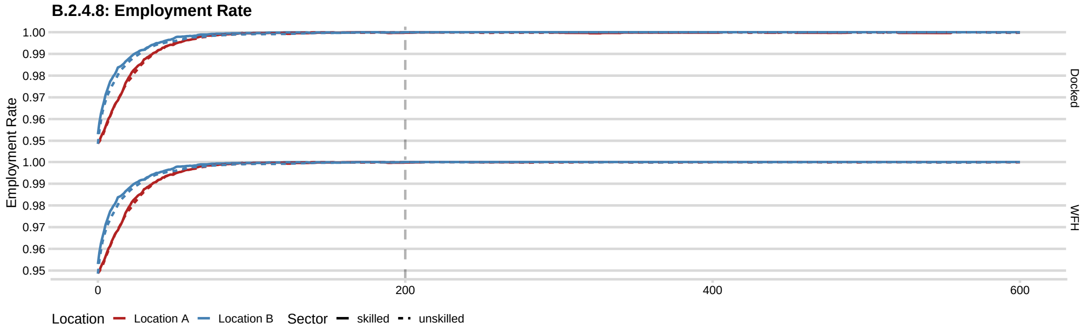
B.2.4.6: Mean Nominal Wage (employed only)



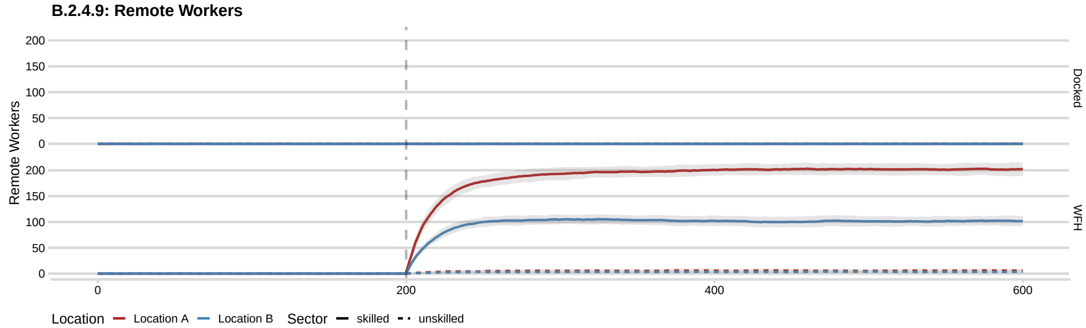
B.2.4.7: Mean Real Wage (employed only)



B.2.4.8: Employment Rate



B.2.4.9: Remote Workers



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