Industry Dynamics and the Minimum Wage: A Putty-Clay Approach

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Abstract

We document three new findings about the industry-level response to minimum wage hikes. First, restaurant exit and entry both rise following a hike. Second, the rise in entry is concentrated in chains, which we show to be more capital-intensive. Third, there is no change in employment among continuing restaurants. We develop a model of industry dynamics based on putty-clay technology and show that it is consistent with these findings. In the model, continuing restaurants cannot change employment, and thus industry-level adjustment occurs through exit of labor-intensive restaurants and entry of capital-intensive ones. We show these three findings are inconsistent with other models of industry dynamics.

Keywords: minimum wage, employment, putty-clay, industry dynamics

JEL codes: L11, E24, J36

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1 Introduction

This paper presents new evidence on how the restaurant industry, the largest U.S. employer of low-wage labor, responds to minimum wage hikes. We document three new empirical findings. First, exit and entry among limited service (i.e. fast food) restaurants rise after a minimum wage hike. Second, the rise in entry is higher among chains, which are more capital intensive. Third, there is no change in employment among continuing limited service restaurants. Together, these results imply an economically small impact on employment two years after a minimum wage hike. We show that an augmented putty-clay model explains these responses but other models of the labor market cannot. To the best of our knowledge, we are the first to provide micro-level evidence supportive of the importance of putty-clay relative to competing models of firm dynamics.

Our empirical findings are derived from the Census of Employment and Wages (QCEW), a database used to compile unemployment insurance payroll records collected by each state's employment office. The QCEW provides detailed information on each establishment's name, location, and employment level at a monthly frequency. We follow Card and Krueger (1994), Addison, Blackburn, and Cotti (2009), and Dube, Lester, and Reich (2010), among others, and compare restaurants that reside in counties near state borders where the minimum wage has risen on one side of the border but not the other. Our results suggest that exit and entry, particularly among chains, increases in the year following a minimum wage hike. By contrast, we find no comparable exit or entry effect among full service restaurants and mixed evidence among other accommodation and food service industries, both of which make less use of low-wage labor.

To interpret these findings, we describe a model of industry dynamics that extends the putty-clay framework of Sorkin (2015) and Gourio (2011) to incorporate endogenous exit as in Campbell (1998). In the model, new entrants can choose from a menu of capital-labor intensities but, once the establishment is built, output is Leontief between capital and labor. In this environment, adjusting the capital-labor mix in response to higher wages requires shutting down labor-intensive establishments and opening capital-intensive establishments. Hence, the model predicts that, given reasonable parameters, both entry and exit rise in response to a minimum wage hike.

Not only does the putty-clay model match our new empirical findings on exit and entry, but it generates two other predictions that appear consistent with the minimum wage literature. First, the model implies that the cost of higher minimum wages are fully passed onto consumers in the form of higher prices (Aaronson (2001), Aaronson, French, and MacDonald (2008)). Second, because continuing restaurants cannot adjust their employment levels, the putty-clay model generates a small short-run employment response, consistent with much of the literature. Importantly, however, under putty-clay technology the disemployment effect of the minimum wage grows over time, as labor intensive incumbent restaurants are slowly replaced with more capital intensive entrants.

This paper is organized as follows. In section 2, we argue that increases in exit and entry resulting from minimum wage hikes are inconsistent with other models of industry dynamics, as well as models incorporating imperfect competition in labor markets. Sections 3 to 5 describe the QCEW data, the estimation strategy, and the results. In section 6, we present the putty-clay model, which is used in section 7 to show how a minimum wage hike impacts exit and entry. A calibration of the model is presented in section 8. Section 9 concludes.

2 Literature Review

Putty-clay models have been effective at matching aggregate business cycle (Gilchrist and Williams (2000) and Atkeson and Kehoe (1999)) and financial market (Gourio (2011)) facts in a number of settings.[1] Our results complement earlier research by documenting that firm entry and exit decisions are consistent with the predictions of putty-clay models. As such, we believe we are the first to provide firm-level empirical evidence supportive of the relevance of putty-clay technology.

The key feature of the putty-clay model – that potential entrants are able to pick a capital-labor ratio that is well-suited to the minimum wage while incumbents are not – is not present in several benchmark models typically used to describe industry dynamics or the impact of minimum wage hikes. For example, Hopenhayn (1992) assumes that factor proportions can

[1] Adjustment cost and job search models can match many of the same facts. But putty-clay has been able to better match both short- and long-run responses to cost shocks such as energy price shocks, whereas adjustment cost models that match short-run movements tend to overstate responses in the long-run (Atkeson and Kehoe (1999)).

freely change. Thus his model predicts an increase in exit and a fall in entry after a minimum wage hike.

Search models contain a mechanism that can potentially match our entry and exit results. In Flinn (2006), a minimum wage hike causes the lowest productivity matches to break up, generating a spike in firm exit. Additional exit increases the number of job searchers, potentially raising the return to posting a vacancy and thus potentially causing a spike in firm entry. That said, because Flinn (2006) is solved in steady-state, as is standard in the literature, his model does not distinguish between entry and exit. Furthermore, Flinn's model does not speak to our continuing firm results because it is a model of a firm vacancy and a single potential worker. Models with multiple worker firms, as in Elsby and Michaels (2013) or Acemoglu and Hawkins (2014), could likely match our exit results but not the lack of employment change among continuing firms.[2]

Thus we believe that putty-clay is a key part of any explanation of the industry dynamics that we empirically document.[3]

Our paper also adds to the voluminous literature on the employment effects of the minimum wage, surveyed by Neumark and Wascher (2008). In particular, we believe we are among the first (see also Rohlin (2011)) to estimate the firm entry and exit responses to minimum wage hikes.[4] Estimation of these responses provides clearer tests of models of low-wage labor market structure, which is critical for evaluating labor market policies to help the poor. Moreover, we show that the putty-clay model is consistent with other market responses to minimum wage hikes that have been studied in the literature, including higher price levels (e.g. Aaronson (2001), Aaronson, French, and MacDonald (2008), and Basker and Khan (2013)), lower profits (Draca, Machin, and Reenen (2011)), and larger disemployment in the long-run than the short-run (Baker, Benjamin, and Stanger (1999), Meer and West (2015),

[2]In a multi-worker firm model, the minimum wage hike would have heterogeneous effects among firms. High-paying firms benefit from the increased ease of finding workers and therefore might expand. Low-paying firms for which the minimum wage hike is binding might contract.

[3]Like us, Jovanovich and Tse (2010) document evidence of a simultaneous spike in entry and exit in response to industry-level technology shocks. They develop a vintage capital model to describe these facts. However, their model still allows firms to freely adjust their capital-labor ratio, and thus would not predict a simultaneous spike in entry and exit after a minimum wage, or other factor price, change.

An important aspect of the putty-clay model is the decision of when to scrap. In this sense we also contribute to the optimal scrapping and replacement literature (Adda and Cooper (2000)) by aggregating to the industry level.

[4]Mayneris, Poncet, and Zhang (2015) study exit responses to minimum wage hikes in China. See also Huang, Loungani, and Wang (2015).

and Sorkin (2015)). Our findings also complement recent work that finds a reduction in hiring and separations after a minimum wage hike (Brochu and Green (2013), Dube, Lester, and Reich (2013), and Gittings and Schmutte (2014)). Our results imply minimum wage hikes increase firm turnover, while their results suggest worker turnover declines among firms that neither enter nor exit following a minimum wage hike. Nevertheless, we see these results as potentially complementary to ours in that each suggest important dynamic dimensions, either within or across establishments, in which there are responses to a labor cost shock.[5]

The only paper that simultaneously studies exit and entry in response to a minimum wage increase to which we are aware is Rohlin (2011). Using detailed firm locations derived from the Dun and Bradstreet Marketplace data files, he finds that state minimum wages hikes instituted between 2003 and 2006 discouraged firm entry but had little impact on the exit and employment of establishments in existence at least 4 years prior. Rohlin identifies exit, entry, and employment effects within miles of state borders, rather than at the coarser county level that we use. However, his main results are reported at the 1 digit (6 industries) SIC level, far too aggregated to distinguish heavy minimum wage users. Strikingly, the largest negative entry appears in manufacturing, where only 10 percent of its workforce is paid within 150 percent of the minimum wage (and only 3% within 110% of the minimum wage). Dube, Lester, and Reich (2010) find no earnings or employment effects of minimum wage hikes in manufacturing. In contrast, just over half of restaurant industry workers are paid within 150 percent of the minimum. Given Rohlin's detailed geographic precision, sample sizes get quite small when results are reported at the more detailed 2 digit industry level.

3 Data

We study the restaurant industry (NAICS 722) because it is the largest employer of workers at or near the minimum wage, accounting for roughly 16 percent of such employees between 2003 and 2006 according to the Current Population Survey's Outgoing Rotation Groups.[6] Moreover, the intensity of use of minimum wage workers in the restaurant industry is amongst

[5]Similarly, Brochu et al. (2015) emphasize different responses among continuing, beginning and ending employment matches, which is analogous to our distinctions among continuing, entering, and exiting firms.

[6]The next largest employer, retail grocery stores, employs just under 5 percent of minimum or near minimum wage workers.

the highest of the industrial sectors (Aaronson and French (2007)). Like many studies before this one (e.g. Katz and Krueger (1992), Card and Krueger (1995), Card and Krueger (2000), Neumark and Wascher (2000), Aaronson and French (2007) and Aaronson, French, and MacDonald (2008)), we concentrate specifically on limited service establishments, which are especially strong users of minimum wage labor.[7]

Our source of restaurant employment data is the Quarterly Census of Employment and Wages (QCEW). Under an agreement with the Bureau of Labor Statistics (BLS), we were granted access to the establishment-level employment data provided in the QCEW data file.[8] The QCEW program compiles unemployment insurance payroll records collected by each state's employment office. The records contain the number of UI-covered employees on the 12^{th} of each month.

The main advantages of the QCEW are that it covers virtually all firms, and has very little measurement error. But as is typical of administrative datasets, information about establishments is sparse. In particular, the key variables are establishment ID, employment, location, and trade and legal name. The former three are used to measure exit, entry, and employment changes by geographic location. The trade/legal name allows us to identify establishments that are part of large chains.[9] For the putty-clay model, chains are interesting because they appear to be more capital intensive than their competitors. According to 10-K reports filed in 2002, the average payroll expense to sales ratio of nine limited service restaurant chains that report domestic payroll and sales information was 26.5 percent.[10] By comparison, the payroll expense to sales ratio of all limited service establishments in the 2002

[7]In "limited service" (LS) outlets, meals are served for on or off premises consumption and patrons typically place orders and pay at the counter before they eat. In "full service" (FS) outlets, wait-service is provided, food is sold primarily for on-premises consumption, orders are taken while patrons are seated at a table, booth or counter, and patrons typically pay after eating. Unfortunately, prior to 2001, industry codes were unable to differentiate limited service and full service outlets. This is one reason why we concentrate on minimum wage changes in the 2000s. Another reason is that there is significant concern about the accuracy of single establishment reporting prior to 2001. We describe this problem below.

[8]We also use data prior to 2003 when the QCEW was referred to as the ES-202.

[9]However, the BLS' confidentiality restrictions do not allow us to disclosure the chain names nor how we developed our list.

[10]We found these companies, which do not correspond to the chains we identify in the QCEW, by using a list of the 50 largest restaurant companies published by Nation's Restaurant News (www.nrn.com). We excluded full service restaurant companies, as well as those that did not file a 10-K in 2002 or did not separately report domestic payroll or revenues in their 10-K. The unweighted and weighted average domestic payroll expense to sales ratio of the 9 companies is 26.5 and 26.6 percent. The ratio ranges from 13.7 to 35.8 percent.

Table 1: State minimum wage increases

		Minimum wage			
Year	State	Old	New	% Change	Comparison states
Jan. 2001	California	5.75	6.25	8.7	OR, NE, AZ
Jan. 2002	California	6.25	6.75	8	OR, NE, AZ
Jan. 2003	Oregon*	6.50	6.90	6.2	ID
Jan. 2004	Illinois	5.15	5.50	6.8	IN, IA, KY, MO
Jan. 2005	Illinois	5.50	6.50	18.2	IN, IA, KY, MO
Aug. 2005	Minnesota	5.15	6.15	19.4	IA, ND, SD
Jan. 2005	DC	6.15	6.60	7.3	MD, VA
Jan. 2006	DC	6.60	7.00	6.1	MD, VA

Note: *Oregon simultaneously instituted an automatic inflation adjustment. Source: Monthly Labor Review, January Issues.

Economic Census of Business Expenses, including chains, was 32 percent.[11]

Our results are derived from five state-level minimum wage hikes – a 17 percent increase in California phased in between January 2001 and January 2002, a 26 percent increase in Illinois phased in between January 2004 and January 2005, a 19 percent increase in Minnesota in August 2005, a 6 percent increase in Oregon in January 2003 that also included the introduction of an annual Consumer Price Index adjustment, and a 14 percent increase in Washington DC phased in during January 2005 and January 2006 – and their adjacent neighboring states in the early- to mid-2000s (see Table 1).[12] While a number of other states passed minimum wage changes during the 2000s, we exclude them because either a) the state QCEW data was not accessible (e.g. Pennsylvania, Massachusetts, New York), b) the change is small (e.g. CPI adjustments), or c) bordering states also raised their minimum wage.[13] Nevertheless, these five states and their neighbors contain significant numbers of restaurants along the borders.

We face three measurement issues with regard to creating a consistent panel of QCEW restaurant employment, entry, and exit.

First, large seasonal employment fluctuations are common among small restaurants, making it appear that they enter and exit. To address this concern, we define an entrant after the

[11] See table 21 (page 122) of http://www2.census.gov/retail/releases/benchmark/2002_bes.pdf

[12] Other than Oregon, the hikes are of comparable size; our results are robust to dropping the Oregon hike.

[13] We also excluded a) Wisconsin as a comparison state to Illinois and Minnesota and b) California as a comparison state to Oregon because of their own minimum wage activity.

hike as an establishment without employment in the year before the hike but with average monthly employment above 15 in each of the two six-month periods starting a year after the hike.[14] Likewise, we define an exit after the hike as an establishment having average employment above 15 employees in each of two six month periods prior to the minimum wage hike and no employment starting a year after the hike. We document how our results vary when we alter the size requirement between 1 and 20 employees.

Second, the BLS did not collect industry NAICS codes until 2001. Therefore, we must use BLS imputations of industry for establishments that exited prior to 2001. This problem is only relevant for one of the five state-level minimum wage hikes that we exploit (the 2001-02 California hike); the other four state-level minimum wage hikes that we study take place well after 2000, and thus imputed data is not needed.

Third, firms sometimes group establishments together for reporting purposes. In a multi-establishment firm, an individual establishment's birth or death may look instead like growth or contraction of a larger continuing firm. Moreover, reporting arrangements can switch between multi-unit and individual establishment reporting over time. Switches from multi-unit to individual establishment reporting ("breakouts") will appear in our data as multiple births with the possibility of a death. Switches from individual to multi-unit reporting ("consolidations") will appear as multiple deaths with the possibility of a birth. Fortunately, using the QCEW Breakout and Consolidations Link (BCL) file, we can identify and drop establishments that were ever involved in a breakout or consolidation. Furthermore, we consider the robustness of our results to imposing an upper bound of 100 employees on establishment size. Like Card and Krueger (2000), we find that our results are robust to changes in this upper-bound.

Appendix tables A4 and A5 provides more details on sample construction and summary statistics.

[14] To take a concrete example, an entrant after the August 2005 hike in Minnesota is an establishment with no employment in August 2004- July 2005 and average employment above 15 in both the August 2006-January 2007 and February 2007-July 2007 periods. For measurement of entry, exit and employment in the period prior to the hike (the "pre-period"), as our difference-in-differences estimator requires,we shift our definitions of entry, exit, and employment back two years to avoid using post-minimum wage hike data. Thus, for the August 2005 Minnesota minimum wage hike, we define a pre-period entrant as having no employment in August 2002- July 2003, and average employment above 15 in both the August 2004-January 2005 and February 2005-July 2005 periods.

4 Empirical Strategy

States might be more likely to raise the minimum wage in good times. Thus, standard state-level difference-in-difference regressions may confound the impact of the minimum wage with the economic conditions that allowed minimum wage legislation to move forward.

To circumvent this problem, we focus on restaurants near state borders. A key advantage of the QCEW is that it contains the establishment's precise location. Geographically nearby restaurants in different states with different minimum wages likely face similar economic environments (other than having a different minimum wage). Our approach compares restaurants near a state border to the nearby restaurants on the other side of the state border.

In particular, we use the Dube, Lester, and Reich (2010) approach and estimate

$$Y_{ispt} \ = \beta w_{ist} + a_{pt} + \alpha_s + \epsilon_{ispt} \tag{1}$$

where Y_{ispt} is the outcome of interest, w_{ist} is the minimum wage faced by firm i in state s at time t, a_{pt} is a full set of border segment-time dummies (e.g., northern California-southern Oregon in Jan. 2013), α_s is a state dummy, ϵ_{ispt} is a residual that is assumed uncorrelated with the minimum wage, and β is the impact of the minimum wage. We concentrate on three measures of Y_{ispt}: the entry rate, the exit rate, and the percent change in employment among continuously-operating establishments. Entry is an indicator variable of whether establishment i existed at time t and not at time $t-1$ and exit is an indicator for whether establishment i existed at time $t-1$ and not time t. For each minimum wage hike, we use two time periods – before and after the hike. We use only restaurants that are in counties on a state border or adjacent to a county on the state border.

Equation (1) is a generalization of the usual difference-in-difference approach. To see this comparison, define t_{np} as the time of the first minimum wage hike for border segment p. Differencing equation (1) yields:

$$(Y_{ispt_{np}+1} - Y_{ispt_{np}-1}) = \beta(w_{ist_{pn}+1} - w_{ist_{pn}-1}) + (a_{pt_{pn}+1} - a_{pt_{pn}-1}) + (\epsilon_{ispt_{np}+1} - \epsilon_{ispt_{np}-1}). \tag{2}$$

Next define the state that raised the minimum wage hike as state s and the comparison state that borders state s but did not have the hike as state ς. Differencing equation (2) across states s and ς yields

$$(Y_{ispt_{np}+1} - Y_{ispt_{np}-1}) - (Y_{i\varsigma pt_{np}+1} - Y_{i\varsigma pt_{np}-1}) = \beta(w_{ist_{pn}+1} - w_{ist_{pn}-1}) \ + residual \qquad (3)$$

where $residual = (\epsilon_{ispt_{np}+1} - \epsilon_{ispt_{np}-1}) - (\epsilon_{ispt_{np}+1} - \epsilon_{ispt_{np}-1})$. As with difference-in-differences, all of the dummy variables related to time and geography vanish. However, there are two key differences between equation (3) and the usual difference-in-differences specification. First, we use the level of the minimum wage rather than a dummy for whether the minimum wage increased. Second, instead of comparing just two states, equation (2) allows us to pool multiple state level minimum wage hikes. Third, our approach does not compare changes across states, but across border segments, so, for example, the change in entry in Northern California is compared to the change in entry in southern Oregon.

5 Results

Table 2 reports the impact of a minimum wage increase on the likelihood of exit (row A), entry (row B), and change in employment of continuing firms (row C). Results for limited service restaurants are presented in columns (1) to (3), full service restaurants in column (4), and establishments that are not restaurants but in the NAICS 72 hospitality and food services industry in columns (5) and (6). Bootstrapped standard errors are in parentheses.

We find that exit of limited service establishments unambiguously rises in the year after a minimum wage increase. A 1 percent increase in the minimum wage causes exit rates in limited service establishments to go up 2.40 percent (standard error of 0.86 percent). Our exit estimates are statistically significant at conventional levels[15] and economically large relative to a baseline limited service annual exit rate of 5.7 percent prior to the minimum wage increase. Exits rise faster among chains than non-chains.

By sharp contrast, there is no impact of a minimum wage increase on the exit of full service restaurants (column (4), row A), nor on other NAICS72 establishments other than restaurants and hotels and motels (column (6), row A), where minimum wage labor share is lower (Aaronson and French (2007)). We do find a large impact on hotels and motels

[15] Results are also statistically significant at the 5 percent level for all establishments when standard errors are clustered at the state-border or state-border-segment level.

Table 2: Elasticity of exit, entry, and employment among continuing firms

	Limited service restaurants			Full service	Hotels/	Other
	All	Chains	Non-chains	restaurants	motels	NAICS72
	(1)	(2)	(3)	(4)	(5)	(6)
A. Exit	2.40	5.27	1.58	-0.75	8.00	-1.98
	(0.86)	(2.14)	(0.91)	(0.75)	(2.11)	(1.12)
	16,191	6,961	9,230	18,184	3,634	4,210
B. Entry	1.37	2.64	0.78	0.14	0.34	1.21
	(0.61)	(1.02)	(0.74)	(0.62)	(1.51)	(1.26)
	16,513	7,188	9,325	18,529	3,606	4,259
C. Change in employment	-0.05	-0.08	-0.04	-0.12	0.35	0.22
among continuing	(0.07)	(0.08)	(0.10)	(0.07)	(0.52)	(0.19)
establishments	14,993	6,555	8,438	16,825	3,324	3,827

Note: Each cell is from a separate regression. For each regression, we report elasticities evaluated at sample means, bootstrapped standard errors (in parentheses), and sample sizes. All estimates include state border-time dummies.

(column (5), row A). Hotels are fairly intensive users of minimum wage labor, although the magnitude of the estimated effect is still surprising.[16]

Row B reports results on entry rates. Similar to exit, entry also increases in the year after a minimum wage hike. We find a one percent increase in the minimum wage leads to 1.37 percent (standard error of 0.61 percentage points) higher entry in the year after the hike relative to the two years prior.[17] This result is again economically large relative to the baseline entry rate of 8.7 percent. The estimated entry effect is larger in establishments affiliated with a chain; entry rises by 2.64 (1.02) percent among chains but 0.78 (0.74) percent among non-chains. Notably, there is again no impact on the entry of full service restaurants, hotel and motels, or other non-restaurant NAICS72 establishments.

[16] We should note, however, that those results are particularly sensitive to the choice of standard error. When we cluster-correct at the state-level, the standard errors from the border state specification rise to 5.30 (from 2.11 with bootstrapping), suggesting the hotel and motel results are highly influenced by a small number of areas. For the other exit estimates, clustering and bootstrapping produces similar estimated standard errors. The cluster-corrected standard error for limited service restaurant exit is somewhat higher as well: 1.24 (cluster) versus 0.86 (bootstrap, column (1)). For full service restaurants, the clustered-corrected standard error is somewhat lower 0.57 (cluster) versus 0.75 (bootstrap, column (4)).

[17] The cluster-corrected standard error for limited service restaurant entry is 1.02, implying a t-statistic of 1.34.

Row C reports results on employment changes among continuing firms. We find little evidence of a significant change in employment among any NAICS72 industries, including limited service restaurants, after a minimum wage increase.

Table 3 provides a number of robustness checks of our benchmark specification (shown again for convenience in row A). Rows (B) to (D) vary the minimum employee size required to be in our sample from 1 to 20 employees. Of particular note, the aggregate limited service exit and entry elasticities are economically small and statistically indistinguishable from zero when the smallest establishments are included (row B). Yet even within this sample, we find economically meaningful, albeit not always statistically significant, differences between chains and non-chains. That is especially the case for entry, where the elasticity for chains is 2.09 (0.76) and is -0.18 (0.37) for non-chains. Once we drop the smallest restaurants (rows C and D), the exit and entry results become larger, although entry remains concentrated among chains regardless of establishment size. This pattern by size may indicate the difficulty of measuring exit and entry among the smallest establishments or, plausibly, that the minimum wage shocks apply in particular to establishments with a sizable workforce, which typically are chains.

Our benchmark specification allows for state border segment dummies. This implies that, for example, the Illinois-Indiana border is part of one labor market. To allow for more flexibility, we also split each border into four equal-length segments (what we call state-border-segments) based on air distance from the southern or eastern-most point of that border and include the state-border segment a_{pt} as a control. Although these results, reported in row (E), are a bit weaker overall, we view their general tenor as again supportive of the benchmark results – exit is fairly broad-based but entry is concentrated among chains.

Other reasonable perturbations, including excluding 100+ employee establishments to avoid concern that there are multi-establishments in the sample (row F) and excluding LA, Orange, and San Diego counties (row G),[18] have little impact on our inferences.[19] Indeed, as a whole, entry, and in some cases exit, differences between chains and non-chains are, if anything, more apparent in many of these cases.

[18] Los Angeles, Orange, and San Diego counties are next to counties bordering Nevada or Arizona, although the vast majority of population in these three counties is far from the border.

[19] We also experimented with using an indicator for a minimum wage hike (i.e. define $w_{st-\tau}$ as 1 if there was a minimum change and 0 otherwise), rather than the magnitude of the increase and found similar results.

Table 3: Robustness of exit and entry responses, limited service (LS) establishments

	Exit			Entry			Employment at continuing firms		
	All LS	Chains	Non-chains	All LS	Chains	Non-chains	All LS	Chains	Non-chains
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Baseline (table 2)	2.40	5.27	1.58	1.37	2.64	0.78	-0.05	-0.08	-0.04
	(0.86)	(2.14)	(0.91)	(0.61)	(1.02)	(0.74)	(0.07)	(0.08)	(0.10)
	16,191	6,961	9,230	16,513	7,188	9,325	14,993	6,555	8,438
B. Minimum	0.05	1.24	-0.12	0.28	2.09	-0.18	-0.10	0.11	-0.17
employee size	(0.75)	(2.06)	(0.68)	(0.34)	(0.76)	(0.37)	(0.11)	(0.16)	(0.14)
is 1	40,739	9,558	31,181	39,769	9,839	29,930	35,684	8,824	26,860
C. Minimum	1.19	3.46	0.57	0.69	2.35	0.00	-0.08	-0.01	-0.11
employee size	(0.63)	(1.72)	(0.71)	(0.49)	(0.92)	(0.59)	(0.06)	(0.09)	(0.09)
is 10	21,354	7,920	13,434	21,700	8,219	13,481	19,571	7,411	12,160
D. Minimum	3.93	6.70	3.14	1.05	2.52	0.38	-0.04	-0.07	-0.02
employee size	(1.06)	(2.52)	(1.09)	(0.75)	(1.34)	(0.93)	(0.09)	(0.09)	(0.13)
is 20	11,928	5,634	6,294	12,019	5,740	6,279	11,093	5,357	5,736
E. State border	2.37	3.64	2.03	0.97	1.85	0.52	-0.06	-0.19	-0.03
segments	(0.93)	(2.44)	(0.98)	(0.70)	(1.12)	(0.85)	(0.09)	(0.09)	(0.14)
	16,100	6,925	9,175	16,452	7,162	9,290	14,942	6,532	8,410
F. Exclude 100+	2.73	5.64	1.84	1.51	2.70	0.94	-0.05	-0.06	-0.04
employee	(0.88)	(2.02)	(0.91)	(0.62)	(1.01)	(0.74)	(0.07)	(0.08)	(0.10)
establishments	15,961	6,899	9,062	16,257	7,120	9,137	14,781	6,497	8,284
G. Exclude LA,	2.09	4.22	1.57	0.95	1.85	0.55	-0.09	-0.15	-0.05
Orange, SD	(0.93)	(2.17)	(0.96)	(0.62)	(1.09)	(0.72)	(0.06)	(0.07)	(0.09)
counties	11,091	4,659	6,432	11,366	4,863	6,503	10,366	4,428	5,938

Note: LS=limited service. Each cell is from a separate regression with elasticities evaluated at sample means and bootstrapped standard errors in parentheses.. Regressions control for state-border fixed effects except row (E) which controls for state border segments. See text for details.

Together, the exit and entry results have roughly offsetting effects on net employment. Combined with the economically small impact on the employment of continuing restaurants, we estimate a disemployment elasticity of -0.1, suggesting that a 10 percent increase to the minimum wage reduces employment about 1 percent, although that estimate is highly imprecise. Precision aside, the point estimate is squarely in the range of previous estimates in the literature, especially those that use a border discontinuity design (Dube, Lester, and Reich (2010); Addison, Blackburn, and Cotti (2009)).

Overall, we read the results as suggesting that restaurant exit and entry rise in response to a minimum wage hike.[20] Although our results are not always statistically precise, exit appears to be fairly broad-based among limited service establishments, whereas entry appears to emerge primarily among chains, which are likely more capital-intensive. Employment barely changes among establishments that remain open throughout the period.

6 The Putty-Clay Model

The previous section of the paper showed that restaurant entry and exit both rise, and employment at existing restaurants changes very little following a minimum wage hike. Furthermore, there is some evidence that exiting restaurants are relatively labor-intensive, whereas entering restaurants are less labor-intensive.

To reconcile these findings, this section develops a model of industry dynamics based on putty-clay technology. When a restaurant enters, it can freely choose its input mix, so its technology is flexible like putty. The novel feature of the putty-clay model is that, after entry, the technology hardens to clay and the input mix is fixed for the life of the restaurant.

Following a minimum wage hike, putty-clay technology introduces an asymmetry between incumbents and potential entrants. Incumbents have a fixed input mix optimized for the old minimum wage but potential entrants choose an input mix optimized for the new minimum wage. This puts incumbent restaurants at a cost disadvantage following a minimum wage hike. Indeed, some exiting incumbents would remain open if they could adjust their input

[20] We have also used the Census' Statistics of U.S. Businesses (SUSB), which collects industry-state-year level information on exit, entry, and employment changes among continuing firms. We find qualitatively similar although quantitatively smaller effects on exit and entry in the SUSB. In particular, we find that restaurant entry and exit both rise within two years of a minimum wage change. No such effect is observed among non-restaurant NAICS72 establishments.

mix. This displacement of incumbents by more capital-intensive entrants generates a spike in entry following the hike.

This section sketches the key features and results of the model. Further details and proofs are in the appendix.

6.1 Production

Restaurants produce food using four inputs: capital, high-skill labor, low-skill labor, and materials. Capital includes land, structures, and machinery. Low-skilled labor is paid the minimum wage. A restaurant bundles inputs to produce initial output y_0.

Ex-ante, restaurants can flexibly substitute between inputs. Restaurants face a CES production function so that production at time 0 (the birth of the restaurant) is

$$y_0 = A_0(\alpha^k k^{\frac{\sigma-1}{\sigma}} + \alpha^m m^{\frac{\sigma-1}{\sigma}} + \alpha^h h^{\frac{\sigma-1}{\sigma}} + (1-\alpha) l^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

where $\alpha = \alpha^k + \alpha^m + \alpha^h$ implies constant returns to scale, A_j is the productivity of a restaurant aged j, σ is the elasticity of substitution, k is capital, m is materials, h is high-skill labor and l is low-skill labor.

Ex-post, the production function is Leontief and restaurants cannot substitute between inputs. Let k', m', h' and l' denote the initial input choices. In subsequent periods, restaurant optimization and constant returns to scale imply that the restaurant either operates with its original proportions at full capacity, or does not operate:

$$y_j = \begin{cases} A_j(\alpha^k k'^{\frac{\sigma-1}{\sigma}} + \alpha^m m'^{\frac{\sigma-1}{\sigma}} + \alpha^h h'^{\frac{\sigma-1}{\sigma}} + (1-\alpha) l'^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} & \text{if } k \geq k', l \geq l', h \geq h', m \geq m' \\ 0 & \text{otherwise.} \end{cases}$$

Once a restaurant has entered, it gradually becomes less productive. A restaurant that is age j has total factor productivity (TFP) $A_j = A_0 e^{-\delta j}$, where δ is the deterministic TFP depreciation term. Given the Leontief assumption and the rate of technology depreciation, output of the restaurant while still alive is $y_j = y_0 e^{-\delta j}$.

6.2 Factor Demands

A restaurant makes two decisions at entry.

First, it decides its input mix which is then fixed once capital is installed. This is a forward-looking decision that therefore considers the effective factor prices over the life of the restaurant. In the model, restaurants assume all prices remain constant over the life of the restaurant, with P the price of the output good and p^m, w^h, and w as the rental prices of materials, high-skill labor, and low-skill labor (i.e., minimum wage), respectively. The restaurant purchases capital at price p^k and can re-sell the capital at price ηp^k.

Second, it decides what exit rule to follow. For the moment take J, the date of restaurant exit, as given. We endogenize J in section 6.3.

Assuming an interest rate r, discounted payments over the life of a new restaurant for materials, high-skill labor, and low-skill labor are $q^m m = (\int_0^J e^{-rj} p^m dj)m$, $q^h h = (\int_0^J e^{-rj} w^h dj)h$, and $q^w = (\int_0^J e^{-rj} w dj)l$, respectively. Recall that capital can be purchased at price p^k and re-sold at price $p^k(1-\eta)$. Therefore, discounted payments to capital are $q^k = p^k(1-e^{-rJ}\eta)k$. Because a restaurant that initially produces y_0 at time 0 will produce $y_j = y_0 e^{-\delta j}$ at time j, total revenue over the life of the restaurant is $q^p y_0 = (\int_0^J e^{-(r+\delta)j} P dj)y_0$. Thus a restaurant's profit over its lifetime is:

$$\pi = q^p A_0(\alpha^k k^{\frac{\sigma-1}{\sigma}} + \alpha^m m^{\frac{\sigma-1}{\sigma}} + \alpha^h h^{\frac{\sigma-1}{\sigma}} + (1-\alpha) l^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} - q^w l - q^m m - q^h h - q^k k. \quad (5)$$

Consequently, an entering restaurant solves the following maximization problem:

$$max_{\{k,m,h,l,J\}} \pi \quad (6)$$

subject to equation (4), which implies the conditional factor demands, given the exit age J:

$$\begin{aligned} l &= \frac{y_0}{[\alpha^k \left(\frac{\alpha^k}{1-\alpha}\frac{q^w}{q^k}\right)^{\sigma-1} + \alpha^m \left(\frac{\alpha^m}{1-\alpha}\frac{q^w}{q^m}\right)^{\sigma-1} + \alpha^h \left(\frac{\alpha^h}{1-\alpha}\frac{q^w}{q^h}\right)^{\sigma-1} + (1-\alpha)]^{\frac{\sigma}{\sigma-1}}}, \\ k &= l\left(\frac{\alpha^k}{1-\alpha}\frac{q^w}{q^k}\right)^{\sigma}, m = l\left(\frac{\alpha^m}{1-\alpha}\frac{q^w}{q^m}\right)^{\sigma}, h = l\left(\frac{\alpha^h}{1-\alpha}\frac{q^w}{q^h}\right)^{\sigma}. \end{aligned} \quad (7)$$

6.3 Exit Age

A restaurant exits when the marginal cost of producing exceeds the marginal benefit. The marginal costs of continued operation is $r\eta p^k k + hw^h + mp^m + lw$, where the first term reflects the shadow cost of staying open and thus delaying the sale of k units of capital at a price ηp^k. Because factor prices are assumed constant and input choices are fixed for the establishment's life, these costs are constant over the life of the restaurant. The flow of marginal benefits at age j are the revenue that the restaurant produces, $e^{-\delta j} y_0 P$. However, unlike marginal costs, marginal benefits decline over the life of a restaurant because TFP falls as the restaurant ages.

Because marginal benefit declines while marginal cost remains constant over the life of the restaurant, eventually it will exit. The exit age J equates the marginal cost and marginal benefit of operating:

$$e^{-\delta J} P y_0 = r\eta p^k k + hw^h + mp^m + lw. \tag{8}$$

Substituting the restaurant's factor demands (equation 7) into the exit age equation (equation 8) results in one equation with two unknowns (P and J). Figure 1 shows the determination of exit age of a restaurant for a given product price P, given parameter values we found to be consistent with the results presented earlier. In this particular case, the restaurant exits during year 18 as the marginal cost of operating exceeds the marginal benefit thereafter.

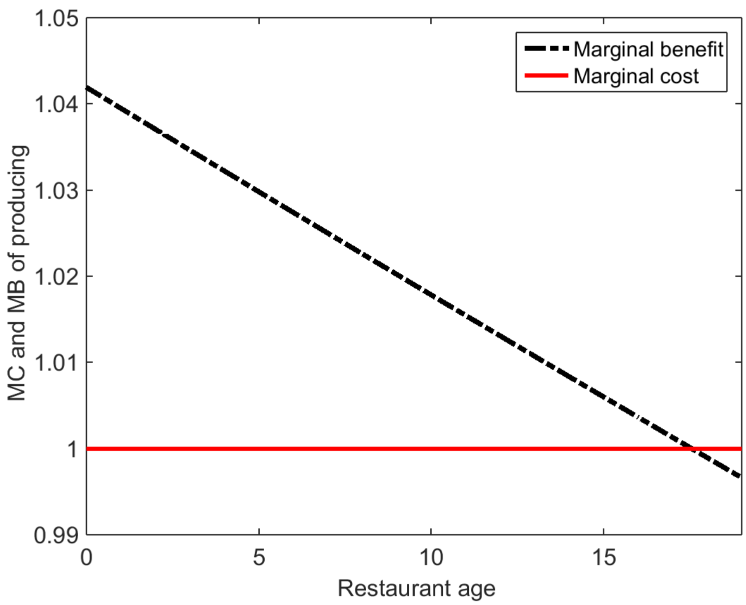
6.4 Market Price Determination

In steady state, free entry pins down the market price. Let f denote the steady state mass of entrants each period. The free entry condition indicates that any profit opportunities will be bid away by new entrants, implying either expected profits or entry is zero:

$$\pi f = 0. \tag{9}$$

In steady state, there is entry so profits are zero. Plugging the conditional factor demands from equations (7) and setting $\pi = 0$ in equation (5), and also using equation (8) yields two equations with two unknowns (P and J). Although the analytic expressions for P and J are complicated, their solution is straightforward.

Figure 1: Determination of exit age in steady state



Note: marginal cost is normalized to 1, so the marginal benefits are relative to marginal cost. Uses parameter values in table 4 and optimal solution to the model.

6.5 Market-Level Equilibrium

Having determined the restaurant's problem, we can solve for the total number of restaurants in a market. The industry faces an isoelastic product demand curve with elasticity γ:

$$Q = \theta P^{-\gamma}. \tag{10}$$

Product market clearing implies that quantity demanded equals quantity supplied, where the quantity supplied is:

$$Q = \int_0^J e^{-j\delta} y_0 f dj. \tag{11}$$

Market supply is comes from restaurants of vintage j supplying quantity $e^{-\delta j} y_0$, the density of each vintage of restaurant (and the mass of entrants each period) f, and the mass of different vintages of incumbent restaurants J. Integrating (11) and rearranging provides an explicit solution to the steady state mass of restaurants that enter in every time period:

$$f = \frac{\delta Q}{y_0(1 - e^{-J\delta})}, \tag{12}$$

where Q is a function of P as in equation (10), and P and J are solved as in section 6.4.

6.6 Steady State Equilibrium

A steady state equilibrium is given by endogenous objects $\{k, h, m, l, Q, P, J, f\}$ taking factor prices $\{p^k, p^m, w^h, w, r\}$ and the environment $\{\delta, \eta, \theta, \gamma, \sigma, \alpha^k, \alpha^m, \alpha^h, y_0\}$ as given such that:

- Restaurants maximize profits, where profits are defined in equation (5);
- Free entry holds (equation 9); and
- The product market clears (equation 11).

7 A Minimum Wage Hike

In this section, we consider a permanent but unexpected minimum wage increase from w_o to w_n at time t_n.[21] Such a hike affects employment through both a scale and substitution effect, sometimes referred to as the Hicks-Marshall channels.

When there is free entry and expected profits are zero, restaurants pass the higher labor costs to consumers in the form of higher prices. As a result, consumers purchase fewer meals and restaurants require fewer inputs. This reduction in sales causes net exit of restaurants immediately following a minimum wage hike and consequently an immediate fall in the employment of minimum wage workers (Aaronson and French (2007)). This channel is sometimes known as the "scale effect."

A hike in the minimum wage also makes low-skilled workers more expensive, causing restaurants to substitute to cheaper factors of production. However, in a putty-clay model, all substitution occurs through entry and exit. Because remaining incumbents maintain their input mix, the substitution effect occurs gradually as the incumbents exit and are replaced

[21] Note t denotes calendar time whereas j denotes the age of a restaurant.

by new restaurants that are free to choose the optimal input mix given the higher price of minimum wage labor.

7.1 Exit Dynamics

Since incumbent restaurants are committed to their input mix, the only margin on which they can respond to higher labor costs is by exiting earlier (or later). In this section, we endogenize exit.

Let $J(w_o, w_n)$ be the exit age of a restaurant that entered when the minimum wage was w_o but is deciding to exit when the minimum wage is w_n. We rewrite the restaurant exit decision equation (8) as

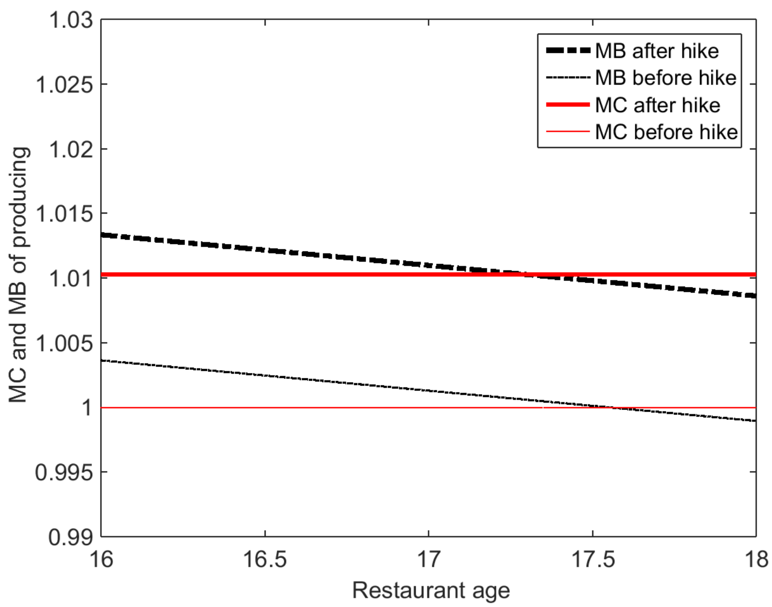
$$e^{-\delta J(w_o,w_n)} P_n y_0 = r\eta p^k k_o + h_o w^h + m_o p^m + l_o w_n, \tag{13}$$

where the left hand side is the marginal benefit of continuing to operate at exit age $J(w_o, w_n)$, and the right hand side is the marginal cost of continuing to operate. Note that we assume the product price jumps to its new steady state P_n immediately. In the next section, we show when this assumption is satisfied.

If $\sigma \leq 1$ and restaurants become more capital-intensive after a minimum wage hike (i.e., $\frac{dk}{dw} \geq 0$), which is the empirically relevant case, then incumbent restaurants respond to the hike by exiting early ($J(w_o, w_n) < J(w_o, w_o)$). Exit spikes as all incumbents between the ages of $J(w_o, w_n)$ and $J(w_o, w_o)$ simultaneously leave the market. This finding is proven in result 2 of Appendix D.

Figure 2 illustrates the exit decision of an incumbent restaurant, both before and after the minimum wage hike. The intersection of the marginal benefit and marginal cost curves determine the age at which the restaurant exits. The marginal benefit of operating at every age rises after the hike because the market price rises. This rise in the market price, however, is not enough to compensate the restaurant for an increase in the wage. Indeed, after the minimum wage hike, the marginal cost curve rises by enough that the restaurant exits earlier than it would have otherwise, i.e., $J(w_o, w_n) < J(w_o, w_o)$. In particular, there is a mass of restaurants caught between the old and the new exit age who exit early. This mass of restaurants produces the spike in exit.

Figure 2: Exit decision of incumbents after a 10% hike in the minimum wage



Note: figure shows marginal benefit and marginal cost of firms both before and after a 10% minimum wage hike. The intersection of the marginal benefit and marginal cost curves determine the exit age. Marginal cost before the hike is normalized to 1. Uses calibrated parameter values in table 4 and optimal solution to the model.

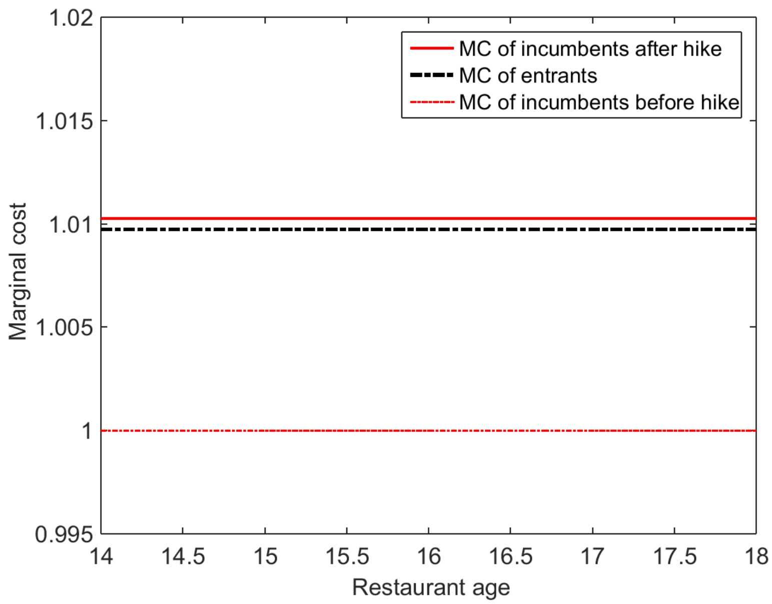
Following the spike in exit, the density of restaurants exiting in a given period remains the same as before the minimum wage hike until all of the incumbent restaurants have exited. Appendix E provides a detailed discussion of exit dynamics.

Figure 3 illustrates the marginal cost curves for incumbents before and after the hike, as well as the marginal cost curve for new entrants after the hike. As a result of the higher minimum wage, marginal cost curves rise for both incumbents and new entrants. However, because new entrants can substitute away from minimum wage labor, their marginal cost rises by less than for incumbents. This cost disadvantage causes incumbents to exit.

7.2 Product price and entry response

Next we show why entry rises and why product prices jump to their new steady state level immediately, as in equation (13), and consistent with the empirical findings of Aaronson (2001) and Aaronson, French, and MacDonald (2008), among others.

Figure 3: Marginal cost curves of incumbents and new entrants before and after a 10% minimum wage hike



Note: Before the minimum wage hike, the marginal cost of incumbents and new entrants is normalized to equal 1. The marginal cost after a 10 percent minimum wage hike is calibrated using parameter values from table 4.

Let P_n be the new steady state product price and $Q_n = \theta P_n^{-\gamma}$ be the new steady state market output. Equation (A29) in Appendix D shows that, to a first-order approximation, market output drops instantly from Q_o to Q_n when:

$$\frac{J(w_o, w_o) - J(w_o, w_n)}{J(w_o, w_o)} \geq \frac{Q_o - Q_n}{Q_o}.$$

The left hand side is the percent of incumbent restaurants that exit, and the right hand side is the percent change in market quantity. If the percent of restaurants exiting is greater than the percent change in market output, new restaurants must enter to fill the gap. This creates a spike in entry. If new restaurants enter, the zero profit condition for new restaurants must hold and output prices jump immediately to their new level. Less than an immediate jump to the new steady state in prices implies no entry. More details on entry behavior can be found in Appendix E.

Table 4: Calibration

Parameter	Value	Description	Source
	A. Exogenously set parameters		
w	1	Minimum wage	Normalization
p^k	1	Capital price	Normalization
w^h	2.76	High skill wage	Aaronson and French (2007)
p^m	1	Materials price	Normalization
σ	0.80	Elasticity of substitution	Aaronson and French (2007)
r	0.05	Interest rate	Standard
	B. Parameters chosen to match targets*		
δ	0.002	Depreciation rate	
η	0.95	Resale price	
γ	0.57	Elasticity of product demand	
α^k	0.49	Productivity of capital	Match s_k
α^h	0.11	Productivity of h labor	Match s_h
α^m	0.34	Productivity of materials	Match s_m

Note: Targets shown in table 5.

8 Calibration

We calibrate the model to the restaurant industry. Our calibration proceeds in two steps. First, we select parameter values $\{\sigma, p^m, p^k, w, w^h, r\}$ for which there are well-agreed-upon values in the literature. Panel A in table 4 report those values. Second, we use a minimum distance estimator to choose 6 parameters, $\{\alpha^k, \alpha^m, \alpha^h, \eta, \delta, \gamma\}$ to match 6 moments – the unique factor shares $\{s^m, s^k, s^h\}$,[22] the average lifespan of a restaurant J, and the elasticities of entry and exit with respect to the minimum wage increase.

While we draw upon Aaronson and French (2007), we augment their calibration targets to accommodate the more sophisticated dynamic model in this paper. The calibration targets are listed in table 5 and the parameters chosen to match those targets are in panel B of table 4. As is standard with CES technology, the moments that identify the α^k, α^m, and α^h parameters are the factor shares s^m, s^k, and s^h. Since the calibration of δ, η,and γ is less standard, we outline our reasoning in more detail.

The moment that identifies the depreciation rate, δ, is the *exit* elasticity. All else equal, δ determines the slope of the marginal benefit curve (see figure 1). If δ is small, then the firms'

[22] $s^l = 1 - (s^m + \ s^k + s^h)$ and thus does not contribute any useful information.

Table 5: Calibration targets and results

Moment	Target	Result	Description	Source
s_K	0.30	0.30	Capital share	Aaronson and French (2007)
s_H	0.20	0.20	High-skill labor share	Aaronson and French (2007)
s_M	0.40	0.40	Materials share	Aaronson and French (2007)
Exit Spike	2.40	2.40	Elasticity of exit with respect to w	This paper
Entry Spike	1.37	1.37	Elasticity of entry with respect to w	This paper
J	17.54	17.54	Average life of a restaurant	This paper

productivity, and consequently marginal benefit of producing, declines slowly over time. In that case, productivity levels are similar for many incumbents, including those that are close to exiting. Thus a small hike causes many restaurants to exit. In contrast, a steep marginal benefit curve (high δ) means that few restaurants are close to exiting and the exit elasticity is small.

The moment that identifies the resale price of capital (η) is the steady state exit age J. All else equal, η determines the relative level of the marginal cost curve shown in figure 1. When the resale price is low, the opportunity cost of re-selling capital is low and thus the marginal cost of operation is low as well. When marginal cost is low, the restaurant remains open longer. In contrast, a high marginal cost curve (high η) signifies that the opportunity cost of operating is high and restaurants exit at a younger age.

Finally, the moment that identifies the elasticity of demand for restaurant output (γ) is the entry elasticity. Because price pass-through immediately follows a minimum wage hike, all else equal, γ determines the change in market quantity and hence output. A low γ indicates that output is unresponsive to a minimum wage hike and most exiting output is replaced by entry. A high γ means that output is very responsive to a minimum wage hike and therefore a spike in entry is unlikely.

The model interprets the estimated spike in exit and entry rates after the minimum wage as a small δ and a high η (table 4, panel B). Indeed, our calibrated value of δ is lower and our calibrated value of η is higher than most estimates in the literature. This is to be expected since we are studying an industry where a large part of the capital stock is land, which has a high resale value and a low depreciation rate. Because both the entry and exit elasticities

Figure 4: Market-level variables after a 10% minimum wage hike

Note: The minimum wage rises 10 percent immediately after time 0. We aggregate the data to an annual frequency. Panels depict the percent change in market prices for the output good, market quantity, and employment, relative to their levels before the hike.

are of similar size, the total disemployment effect is small. Our product demand elasticity is similar to Aaronson and French's (2007) preferred value of 0.5. This is lower than the estimate in Harasztosi and Lindner (2015). More detail on the calibration is in Appendix A.

8.1 The effects of a minimum wage hike

Figure 4 shows industry price, quantity and employment in the 17 years following a 10 percent one-time, unanticipated and permanent minimum wage increase from steady state.[23] Because of entrants, the product price jumps to the new steady state immediately, about 0.97 percent

[23]The hike occurs at time 0. We aggregate the model's predicted response to an annual frequency to be consistent with the data.

higher than before the hike. That price increase implies an elasticity of 0.097, in line with the evidence discussed in Aaronson and French (2007). Because the price jumps immediately, the industry quantity jumps to its new steady state level as well.

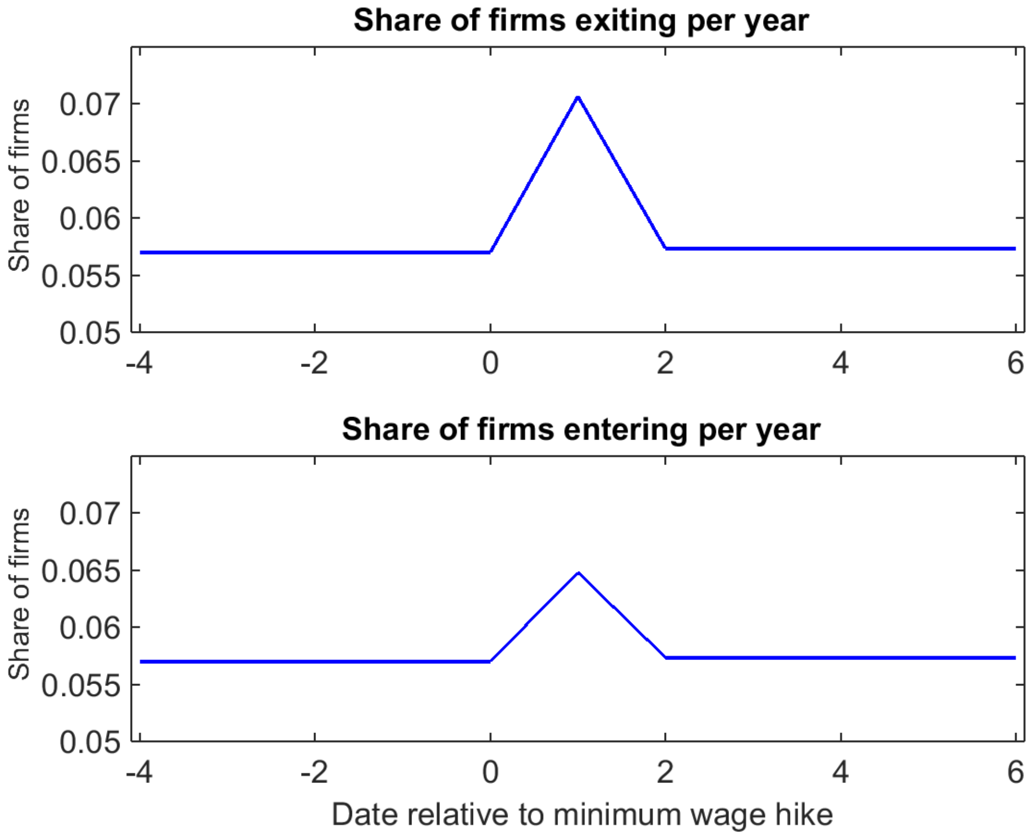
Employment responds more slowly to the minimum wage hike. After one year, total employment (high- and low-skill) falls by 0.8 percent, implying an elasticity of -0.08. But the employment response grows over time such that in the steady state determined by the new minimum wage, the long-term elasticity is -0.40. This graph illustrates a key feature of the putty-clay model. Because restaurants turn over slowly following a minimum wage hike, the full employment effect of the minimum wage also unfolds slowly.

The employment results highlight two useful and related insights. First, putty-clay models imply larger long-run effects. While the evidence on long-run effects is scarce, what little exists is consistent with this prediction (Baker, Benjamin, and Stanger (1999)). Second, the minimum wage hike causes a trend in employment after the hike. Typical difference-in-difference estimators measure short-run effects, assuming that the minimum wage only causes a one time jump down in employment. Both of these issues will cause a difference-in-differences estimator to understate the true disemployment effect of the minimum wage.

Why is the short-run employment effect so small? Recall the two Hicks-Marshall channels by which employment falls. The first is the scale effect. Free entry implies that expected profits are 0, so restaurants will pass the higher labor costs to consumers in the form of higher prices. As a result, consumers will purchase fewer meals and restaurants will require fewer inputs. The reduction in sales causes net exit of restaurants immediately following a minimum wage hike and consequently an immediate fall in the employment of minimum wage workers. Appendix E shows that product prices rise in proportion to minimum wage labor's share of costs and Aaronson and French (2007) compute that, even at fast food restaurants, low-skill labor is only about 10 percent of total costs. Since the scale effect is in proportion to minimum wage labor's share, the scale effect is small and only modestly reduces employment.

The second channel is the substitution effect. A hike in the minimum wage makes low-skilled workers more expensive, causing restaurants to substitute to cheaper factors of production. However, in a putty-clay model, all substitution occurs through entry and exit. Because remaining incumbent restaurants maintain their input mix, the substitution effect

Figure 5: Share of firms entering and exiting after a 10% minimum wage hike

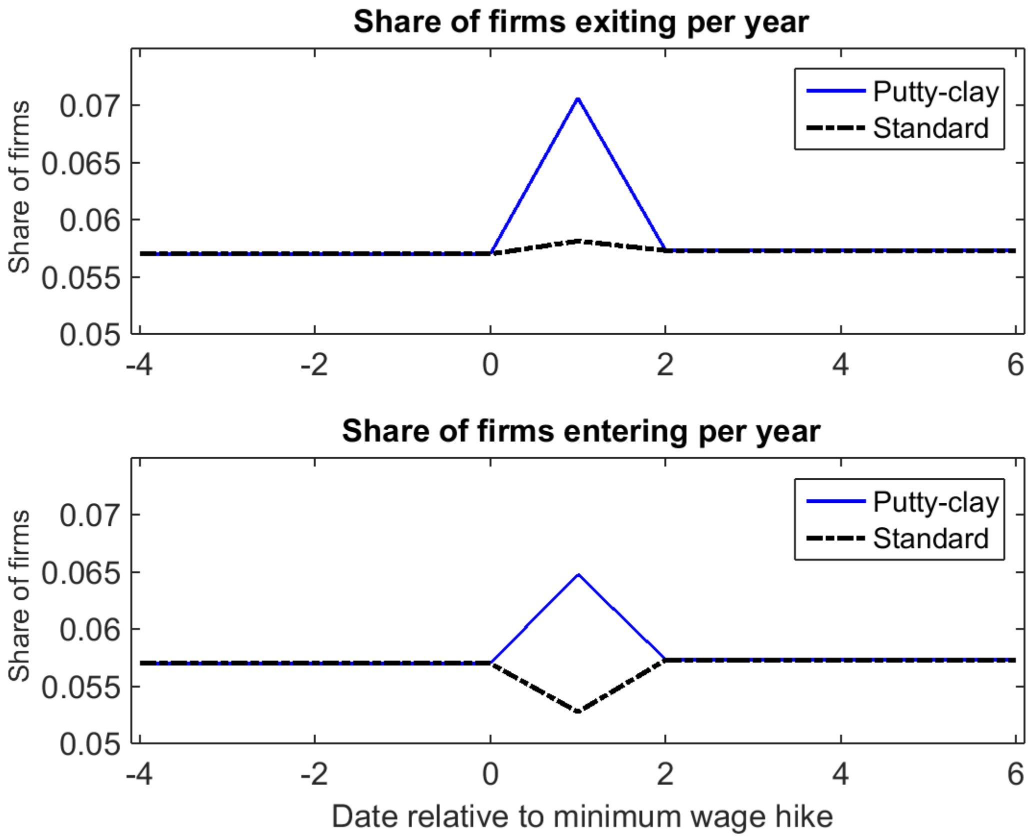


Note: The exit share is the share of firms in operation a year ago that are currently not in operation. The entry share is the share of firms currently in operation that were not in operation a year ago. In these calibrations, the minimum wage is boosted by 10 percent immediately after time 0.

occurs gradually only as the incumbent restaurants exit and are replaced by new restaurants that are free to choose the optimal input mix given the new price of minimum wage labor.

The net employment response masks an increase in both entry and exit following a minimum wage hike. The upper panel of Figure 5 shows the total amount of exit following the minimum wage hike, and the lower panel shows the same for entry. So long as product demand is elastic, market quantity falls and thus the exit rate is higher than the entry rate. However, given our parameter values, the spike in exit is so large that there is a spike in entry also.

Figure 6: Share of firms entering and exiting after a 10% minimum wage hike, putty clay model versus standard model



Note: The "putty-clay" line depicts the entry and exit behavior using our calibrated putty-clay model. The "standard" line depicts entry and exit behavior when restaurants can adjust their factor demands after a minimum wage hike. The exit share is the share of firms in operation a year ago that are not currently in operation. The entry share is the share of firms not in operation a year prior that are in operation. In these calibrations, the minimum wage is boosted by 10 percent immediately after time 0.

8.2 The contribution of putty-clay to entry and exit behavior

Figure 6 contrasts entry and exit behavior of the putty-clay model with an alternative where incumbent firms can re-optimize their factor mix after the hike. Otherwise, the models are identical.

In the absence of putty-clay technology (where restaurants can re-optimize their factor mix after the hike), there is still an increase in exit after the minimum wage hike if $\sigma < 1$.

However, the increase is barely noticeable. Since the exit response generated by the model without putty-clay technology is smaller, the entry response will be smaller as well. In fact, entry drops. This decline is a robust qualitative feature of a model without putty-clay technology, highlighting that putty-clay is central to understanding the rise in entry.

9 Conclusion

We present new evidence on the effect of minimum wage hikes on establishment entry, exit, and employment among employers of low-wage labor. We show that small net employment changes in the restaurant industry may hide a significant amount of establishment churning that arises in response to a minimum wage hike. To capture these dynamics, we develop a putty-clay model with endogenous entry and exit. The key feature of the putty-clay model is that, after entry, technology and input mix is fixed for the life of the restaurant. After minimum wage hikes, inflexible incumbents are replaced by potential entrants who can optimize on input mix. Thus, the model is capable of predicting both restaurant entry and exit in response to a minimum wage hike.

Furthermore, we show that the putty-clay model generates employment and output price responses to minimum wage hikes that are consistent with those reported in the literature. In particular, putty-clay yields sluggish employment responses to minimum wage hikes, with a short-run disemployment effect of around -0.1 that grows to -0.4 in the long-run. Similarly, the model predicts that restaurant prices are immediately and fully passed onto consumers in the form of higher prices, again consistent with the literature.

Other models, such as those that incorporate adjustment costs, can reconcile some of these facts but not others, especially the simultaneous rise of exit and entry. As such, we believe putty-clay models could be potentially useful for understanding the response to other labor market policies, including taxes, hiring subsidies, and firing costs and we view our paper as a novel contribution in that we provide micro level evidence on the empirical relevance of putty-clay in an important policy setting.

References

Aaronson, Daniel. 2001. "Price Pass-Through and the Minimum Wage." *Review of Economics and Statistics* 83 (1):158–169.

Aaronson, Daniel and Eric French. 2007. "Product Market Evidence on the Employment Effects of the Minimum Wage." *Journal of Labor Economics* 25 (1):167–200.

Aaronson, Daniel, Eric French, and James MacDonald. 2008. "The minimum wage, restaurant prices, and labor market structure." *Journal of Human Resources* 43 (3):688–720.

Acemoglu, Daron and William B. Hawkins. 2014. "Search with multi-worker firms." *Theoretical Economics* 9:583–628.

Adda, Jerome and Russell Cooper. 2000. "Balladurette and Juppette: A Discrete Analysis of Scrapping Subsidies." *Journal of Political Economy* 108 (4):778–806.

Addison, John T., McKinley L. Blackburn, and Chad D. Cotti. 2009. "Do minimum wages raise employment? Evidence from the US retail-trade sector." *Labour Economics* 16 (4):397–408.

Atkeson, Andrew and Patrick J. Kehoe. 1999. "Models of Energy Use: Putty-Putty versus Putty-Clay." *American Economic Review* 89 (4):1028–1043.

Baker, Michael, Dwayne Benjamin, and Shuchita Stanger. 1999. "The High and Lows of the Minimum Wage Effect: A time-series cross-section study of the Canadian Law." *Journal of Labor Economics* 17 (2):2318–2350.

Basker, Emek and Muhammad Taimur Khan. 2013. "Does the Minimum Wage Bite into Fast-Food Prices?" Working paper.

Brochu, Pierre and David A. Green. 2013. "The Impact of Minimum Wages on Labor Market Transitions." *The Economic Journal* 123:1203–1235.

Brochu, Pierre, David A. Green, Thomas Lemieux, and James Townsend. 2015. "The Minimum Wage, Turnover, and the Shape of the Wage Distribution." Working paper.

Campbell, Jeffrey R. 1998. "Entry, Exit, Embodied Technology, and Business Cycles." *Review of Economic Dynamics* 1 (2):371–408.

Card, David and Alan B. Krueger. 1994. "Minimum Wages and Employment: A Case Study of the Fast Food Industry in New Jersey and Pennsylvania." *American Economic Review* 84 (4):772–784.

———. 1995. *Myth and Measurement: The New Economics of the Minimum Wage*. Princeton, NJ: Princeton University Press.

———. 2000. "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania: Reply." *American Economic Review* 90 (5):1397–1420.

Draca, Mirko, Stephen Machin, and John Van Reenen. 2011. "Minimum Wages and Firm Profitability." *American Economic Journal: Applied* 3:129–151.

Dube, Arindrajit, T. William Lester, and Michael Reich. 2010. "Minimum Wage Effects Across State Borders: Estimates Using Contiguous Counties." *Review of Economics and Statistics* 92 (4):945–964.

———. 2013. "Do Frictions Matter in the Labor Market? Accessions, Separations and Minimum Wage." Working paper.

Elsby, Michael W. L. and Ryan Michaels. 2013. "Marginal Jobs, Heterogeneous Firms, and Unemployment Flows." *American Economic Journal: Macroeconomics* 5 (1):1–48.

Flinn, Christopher. 2006. "Minimum Wage Effects on Labor Market Outcomes under Search, Matching, and Endogenous Contact Rates." *Econometrica* 74 (4):1013–1062.

Gilchrist, Simon and John C. Williams. 2000. "Putty-Clay and Investment: A Business Cycle Analysis." *Journal of Political Economy* 108 (5):928–960.

Gittings, K. Raj and Ian M. Schmutte. 2014. "Getting Handcuffs on an Octopus: Minimum Wages, Employment, and Turnover." Working paper.

Gourio, Francois. 2011. "Putty-Clay Technology and Stock Market Volatility." *Journal of Monetary Economics* 58 (2):117–131.

Harasztosi, Peter and Attila Lindner. 2015. “Who Pays for the Minimum Wage?” Working paper.

Hopenhayn, Hugo A. 1992. “Entry, Exit, and firm Dynamics in Long Run Equilibrium.” *Econometrica* 60 (5):1127–1150.

Huang, Yi, Prakash Loungani, and Gewei Wang. 2015. “Minimum Wages and Employment Dynamics: Evidence from China.” Working paper.

Jovanovich, Boyan and Chung-Yi Tse. 2010. “Entry and exit echoes.” *Review of Economics Dynamics* 13:514–536.

Katz, Lawrence and Alan Krueger. 1992. “The effect of the minimum wage on the fast-food industry.” *Industrial and Labor Relations Review* 46 (1):6–21.

Mayneris, Florian, Sandra Poncet, and Tao Zhang. 2015. “The cleansing effect of minimum wages: Minimum wages, firm dynamics and aggregate productivity in China.” Working paper.

Meer, Jonathan and Jeremy West. 2015. “Effects of the Minimum Wage on Employment Dynamics.” Working paper.

Neumark, David and William L. Wascher. 2000. “Minimum wages and employment: A case study of the fast-food industry in New Jersey and Pennsylvania: Comment.” *The American Economic Review* 90 (5):1362–1396.

———. 2008. *Minimum Wages*. Cambridge, MA: MIT Press.

Rohlin, Shawn M. 2011. “State minimum wages and business location: Evidence from a refined border approach.” *Journal of Urban Economics* 69 (1):103–117.

Sorkin, Isaac. 2015. “Are There Long-Run Effects of the Minimum Wage?” *Review of Economic Dynamics* 18 (2):306–333.

Appendix A: Calibration

This appendix details the parameter values we use in the calibration exercise, and borrows heavily from Aaronson and French (2007).

Factor Shares, s^l, s^h, s^m, s^k There are a number of sources for labor share, all of which tend to report similar numbers for the food away from home industry. First, 10-K company reports contain payroll to total expense ratios. Of the 17 restaurant companies that appear in a search of 1995 reports using the SEC's Edgar database, the unconditional mean and median of this measure of labor share is 30 percent and it ranges from 21 to 41 percent.[24] These numbers are in-line with a sampling of 1995 corporate income tax forms from the Internal Revenue Service's Statistics on Income Bulletin. Because operating costs are broken down by category, it is possible to estimate labor's share.[25] According to these tax filings, labor cost as a share of operating costs for eating place partnerships is roughly 33 percent. Consequently, we set $s^l + s^h$ to 30 percent.

We are particularly interested in labor share in low wage firms. We use the 1997 Economic Census for Accommodations and Food Services, which reports payroll for full service (FS) and limited service (LS) restaurants. LS includes fast-food stores and any restaurant without sit-down service and where customers pay at the counter prior to receiving their meals. Therefore, they tend to be the primary employer of minimum wage labor. According to this 1997 census, labor share, as a fraction of sales, is slightly higher at FS (31 percent) than LS (25 percent) stores.[26] Therefore, there is little evidence of a significant difference in labor share across establishment type.

Aaronson and French (2007) use Current Population Survey data to show that $\frac{1}{3}$ of restaurant industry workers are paid less than 150% of the minimum wage, and are thus likely to be affected by the minimum wage. This group accounts for 17% of the wage bill in the restaurant industry. Since labor's share is 0.3, minimum wage workers have a $0.3 \times 17\% = 5.1\%$ share in expenses overall. Given our calculations on the number of restaurants that are

[24] The search uses five keywords: restaurant, steak, seafood, hamburger, and chicken.

[25] The IRS claims that labor cost is notoriously difficult to decompose for corporations and therefore we restrict our analysis to partnerships, where there is less concern about reporting.

[26] Several 10-K reports of individual restaurant companies show that wages account for 85 percent of compensation. Therefore, labor's share based on compensation is roughly 36 and 29 percent at full and limited service restaurants.

limited service, and the fact that limited service restaurants use minimum wage labor much more intensively than the restaurant industry as a whole, we set $s^l = 0.1$ and $s^h = 0.2$.

Based on the same sample of company financial reports used to compute $s^l + s^h$, we assume that capital's share is 30 percent and material's share is 40 percent.

The Elasticity Parameter σ Aaronson and French (2007) could not find estimates of the elasticity of substitution σ for restaurants, but review the literature on estimates of σ, and find that $\sigma = 0.8$ is an average estimate in the literature.

Targets: age, exit and entry elasticity The exit age of a restaurant, J, is picked to match the average exit probability of 0.057 (see appendix Table A5): $J = \frac{1}{0.057} = 17.54$ years. The entry and exit elasticities are from table 2.

Appendix B: Comparative Static Result: Product Price.

This appendix first derives the explicit expression for the market price almost in terms of model fundamentals (the exit age, (J), is left implicit). The appendix then solves for the elasticity of product price with respect to the minimum wage.

The (effective) product price

Free entry implies that the maximand in (6) is equal to zero. Substituting in the equilibrium factor demands from equation (7) and the definition of y_0 from equation (5) to the maximand in equation (6) set equal to zero:

$$q^p y_0 = q^k k + q^m m + q^h h + q^w l \tag{A1}$$

$$q^p = \frac{\left(q^k \left(\frac{q^w}{q^k}\frac{\alpha^k}{1-\alpha}\right)^\sigma + q^m \left(\frac{q^w}{q^m}\frac{\alpha^m}{1-\alpha}\right)^\sigma + q^h \left(\frac{q^w}{q^h}\frac{\alpha^h}{1-\alpha}\right)^\sigma + q^w\right)}{\left(\alpha^k \left(\frac{q^w}{q^k}\frac{\alpha^k}{1-\alpha}\right)^{\sigma-1} + \alpha^m \left(\frac{q^w}{q^m}\frac{\alpha^m}{1-\alpha}\right)^{\sigma-1} + \alpha^h \left(\frac{q^w}{q^h}\frac{\alpha^h}{1-\alpha}\right)^{\sigma-1} + (1-\alpha)\right)^{\frac{\sigma}{\sigma-1}}}. \tag{A2}$$

We now want to simplify each term. For example, the term involving low-skill wages simplifies as follows:

$$\frac{q^w}{1-\alpha}\alpha^k \left(\frac{\alpha^k}{1-\alpha}\frac{q^w}{q^k}\right)^{\sigma-1} = q^k \left(\frac{q^w}{q^k}\frac{\alpha^k}{1-\alpha}\right)^\sigma. \tag{A3}$$

Exploiting analogous simplifications on each term in (A1) gives the effective product price:

$$q^p = \frac{q^w}{1-\alpha}\left(\alpha^k\left(\frac{\alpha^k}{1-\alpha}\frac{q^w}{q^k}\right)^{\sigma-1} + \alpha^m\left(\frac{\alpha^m}{1-\alpha}\frac{q^w}{q^m}\right)^{\sigma-1} + \alpha^h\left(\frac{\alpha^h}{1-\alpha}\frac{q^w}{q^h}\right)^{\sigma-1} + (1-\alpha)\right)^{\frac{-1}{\sigma-1}}. \tag{A4}$$

To convert the effective product price to the product price, explicitly solve the expression relating these two prices given in the paragraph above equation (5):

$$q^p = \int_0^J e^{-(r+\delta)j} P dj \tag{A5}$$

$$q^p \frac{r+\delta}{1-e^{-(r+\delta)J}} = P. \tag{A6}$$

Combining equations (A4) and (A5) gives an explicit expression for the product price:

$$P = \frac{r+\delta}{1-e^{-(r+\delta)J}}\frac{q^w}{1-\alpha}\left[\alpha^k\left(\frac{q^w}{q^k}\frac{\alpha^k}{1-\alpha}\right)^{\sigma-1} + \alpha^m\left(\frac{q^w}{q^m}\frac{\alpha^m}{1-\alpha}\right)^{\sigma-1} + \alpha^h\left(\frac{q^w}{q^h}\frac{\alpha^h}{1-\alpha}\right)^{\sigma-1} + (1-\alpha)\right]^{\frac{-1}{\sigma-1}}. \tag{A7}$$

Response of product price to a minimum wage hike

We are interested in the effect of a change in the low-skill wage on the price level. The effective low-skill wage, $q^w = \frac{1-e^{-rJ}}{r}w$, depends on w directly and because J, the exit age, depends on w. We study the effect of w on J in appendix C. To see where J enters the expression, substitute in the definitions of the effective prices in the paragraph above equation (5) into (A7). To keep the expression somewhat more compact, define:

$$\hat{k}(J,w) = \left(\frac{w}{p^k}\frac{\frac{1-e^{-rJ}}{r}}{1-e^{-rJ}\eta}\frac{\alpha^k}{1-\alpha}\right)^{\sigma}, \hat{m}(w) = \left(\frac{w}{p^m}\frac{\alpha^m}{1-\alpha}\right)^{\sigma}, \text{ and } \hat{h}(w) = \left(\frac{w}{p^h}\frac{\alpha^h}{1-\alpha}\right)^{\sigma}.$$

Then the product price depends on the flow prices and exit age (J) as follows, where in this expression only we write $J(w)$ to emphasize the dependence of J on w:

$$P = \frac{r+\delta}{r}\frac{1-e^{-rJ(w)}}{1-e^{-(r+\delta)J(w)}}\frac{w}{1-\alpha}\left[\alpha^k\hat{k}(J(w),w)^{\frac{\sigma-1}{\sigma}} + \alpha^m\hat{m}(w)^{\frac{\sigma-1}{\sigma}} + \alpha^h\hat{h}(w)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)\right]^{\frac{-1}{\sigma-1}}. \tag{A8}$$

Take the derivative of the product price with respect to the low-skill wage:

$$
\begin{aligned}
\frac{\partial P}{\partial w} = &\left\{ \frac{r+\delta}{r} \frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}} \frac{1}{1-\alpha} + \frac{r+\delta}{r} \frac{w}{1-\alpha} \frac{\partial \frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}}}{\partial J} \frac{\partial J}{\partial w} \right\} \\
&\times \left[\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \hat{h}^{\frac{\sigma-1}{\sigma}} + (1-\alpha) \right]^{\frac{-1}{\sigma-1}} \\
&- \frac{r+\delta}{r} \frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}} \frac{w}{1-\alpha} \left[\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \hat{h}^{\frac{\sigma-1}{\sigma}} + (1-\alpha) \right]^{\frac{-1}{\sigma-1}-1} \\
&\times \left[\alpha^k \frac{1}{w} \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \frac{1}{w} \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \frac{1}{w} \hat{h}^{\frac{\sigma-1}{\sigma}} + \frac{1}{\sigma} \alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}-1} \left(\frac{\partial \hat{k}}{\partial J} \frac{\partial J}{\partial w} \right) \right].
\end{aligned} \tag{A9}
$$

Convert to an elasticity (the expression for $\frac{w}{P}$ comes from rearranging (A8)):

$$
\begin{aligned}
\frac{\partial P}{\partial w} \frac{w}{P} = &\frac{1-\alpha}{\left[\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \hat{h}^{\frac{\sigma-1}{\sigma}} + (1-\alpha) \right]} \\
&- \frac{\frac{1}{\sigma} \alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} \left(\frac{\partial \hat{k}}{\partial J} \frac{J}{\hat{k}} \frac{\partial J}{\partial w} \frac{w}{J} \right)}{\left[\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \hat{h}^{\frac{\sigma-1}{\sigma}} + (1-\alpha) \right]} + \frac{\partial \frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}}}{\partial J} \frac{J}{\frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}}} \frac{\partial J}{\partial w} \frac{w}{J}.
\end{aligned} \tag{A10}
$$

To simplify this expression further, derive expressions for some steady state factor shares. For low-skill labor:

$$
\begin{aligned}
s_L &= \frac{q^w}{q^k \hat{k} + q^m \hat{m} + q^h \hat{h} + q^w} && \text{(A11)} \\
&= \frac{1-\alpha}{\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \hat{h}^{\frac{\sigma-1}{\sigma}} + (1-\alpha)} && \text{(A12)}
\end{aligned}
$$

For capital:

$$
s_K = \frac{\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}}}{\alpha^k \hat{k}^{\frac{\sigma-1}{\sigma}} + \alpha^m \hat{m}^{\frac{\sigma-1}{\sigma}} + \alpha^h \hat{h}^{\frac{\sigma-1}{\sigma}} + (1-\alpha)}. \tag{A13}
$$

Hence, substituting the factor shares ((A11) and (A13)) into (A10) gives the following expression for the elasticity of the product price with respect to the low-skill wage:

$$
\frac{\partial P}{\partial w} \frac{w}{P} = s_L - \frac{1}{\sigma} s_K \left(\frac{\partial \hat{k}}{\partial J} \frac{J}{\hat{k}} \frac{\partial J}{\partial w} \frac{w}{J} \right) + \frac{\partial \frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}}}{\partial J} \frac{J}{\frac{1-e^{-rJ}}{1-e^{-(r+\delta)J}}} \frac{\partial J}{\partial w} \frac{w}{J}.
$$

The dependence of the exit age on the low-skill wage introduces two additional terms relative to the standard result that the product price elasticity is s_L.

Appendix C: Response of Steady State Exit Age J to Minimum Wage Hike

Start with the exit condition for a restaurant, equation (8), which equates the marginal cost and the marginal benefit of operating in the period. Everything in this expression except for J can be written in terms of model primitives. Thus, the expressions gives an implicit equation for J:

$$\underbrace{\frac{r+\delta}{r}\frac{e^{-\delta J}-e^{-(r+\delta)J}}{1-e^{-(r+\delta)J}}}_{a}$$
$$\times\frac{1}{1-\alpha}\left(\alpha^k\underbrace{\left(\frac{\alpha^k}{1-\alpha}\frac{1}{rp^k}\frac{1-e^{-(r)J}}{1-\eta e^{-rJ}}\right)^{\sigma-1}}_{b}+\alpha^m\left(\frac{\alpha^m}{1-\alpha}\frac{1}{p^m}\right)^{\sigma-1}+\alpha^h\left(\frac{\alpha^h}{1-\alpha}\frac{1}{w^h}\right)^{\sigma-1}\right)=$$
$$r\eta p^k\underbrace{\left(\frac{\alpha^k}{1-\alpha}\frac{1}{rp^k}\frac{1-e^{-(r)J}}{1-\eta e^{-rJ}}\right)^{\sigma}}_{c}+\left(\frac{\alpha^h}{1-\alpha}\frac{1}{w^h}\right)^{\sigma}w^h+\left(\frac{\alpha^m}{1-\alpha}\frac{1}{p^m}\right)^{\sigma}p^m+\underbrace{\left(1-\frac{e^{-\delta J}-e^{-(r+\delta)J}}{1-e^{-(r+\delta)J}}\frac{r+\delta}{r}\right)}_{d}\underbrace{w^{1-\sigma}}_{e}. \tag{A14}$$

We use this expression for J to characterize the response of J to a change in w.

Result 1. *When* $\sigma<1$, $\frac{\partial J}{\partial w}<0$. *When* $\sigma=1$, $\frac{\partial J}{\partial w}=0$.

Proof. The proof is by contradiction. It relies on facts collected in Table A1. The table shows what happens to the terms in equation (A14) that depend on J and w following an increase in w when $\sigma<1$ under two different assumptions on J: first if J increases and second if J stays constant. Straightforward (though tedious) calculations sign the derivatives in column (4).

Suppose that $\frac{\partial J}{\partial w}>0$ so that both w and J increase simultaneously. Column (2) of Table A1 shows that the equality no longer holds since the left hand side of equation (A14) decreases while the right hand side of equation (A14) increases. Hence, $\frac{\partial J}{\partial w}\leq 0$ when $\sigma<1$.

Suppose that $\frac{\partial J}{\partial w}=0$ so that w increases and J remains constant. Column (3) of Table A1 shows that the equality no longer holds since the left hand side of equation (A14) remains

Table A1: Effect of an increase in w on equation (A14) for $\sigma < 1$.

	$J \uparrow$	J constant	
Term	Movement	Movement	Reason
(1)	(2)	(3)	(4)
a	$\downarrow$	*constant*	$\frac{\partial}{\partial J}\frac{e^{-\delta J}-e^{-(r+\delta)J}}{1-e^{-(r+\delta)J}} < 0$
b	$\downarrow$	*constant*	$\frac{\partial}{\partial J}\left(\frac{\alpha^k}{1-\alpha}\frac{1}{r}\frac{w}{p^k}\frac{1-e^{-(r)J}}{1-\eta e^{-rJ}}\right) > 0$
c	$\uparrow$	*constant*	$\frac{\partial}{\partial J}\left(\frac{\alpha^k}{1-\alpha}\frac{1}{r}\frac{w}{p^k}\frac{1-e^{-(r)J}}{1-\eta e^{-rJ}}\right) > 0$
d	$\uparrow$	*constant*	$\frac{\partial}{\partial J}\left(-\frac{e^{-\delta J}-e^{-(r+\delta)J}}{1-e^{-(r+\delta)J}}\right) > 0$
e	$\uparrow$	$\uparrow$	$\frac{\partial w^{1-\sigma}}{\partial w} = (1-\sigma)w^{-\sigma} > 0$, $\left(1-\frac{e^{-\delta J}-e^{-(r+\delta)J}}{1-e^{-(r+\delta)J}}\frac{r+\delta}{r}\right) > 0$
$LHS(A14)$	$\downarrow$	*constant*	
$RHS(A14)$	$\uparrow$	$\uparrow$	

constant while the right hand side of equation (A14) increases. Hence, $\frac{\partial J}{\partial w} \neq 0$ when $\sigma < 1$.

Combining, when $\sigma < 1$ then $\frac{\partial J}{\partial w} < 0$.

The equality in equation (A14) must still hold following an increase in w. When $\sigma = 1$, the term involving w drops out, and so $\frac{\partial J}{\partial w} = 0$. ∎

Appendix D: Exit behavior and market price response

This appendix proceeds in two steps:

- Solve for the exit behavior of the incumbent assuming the product price jumps to the new steady state level immediately.
- Derive the condition for the product price to jump immediately to its new steady state level.

Exit behavior assuming market price jumps to its new steady state

Result 2. *If $\sigma < 1$ and $\frac{\partial k}{\partial w} \geq 0$ then for a minimum wage increase $J(w_o, w_n) < J(w_n, w_n) < J(w_o, w_o)$. If $\sigma = 1$ and $\frac{\partial k}{\partial w} \geq 0$ then for a minimum wage increase $J(w_o, w_n) < J(w_n, w_n) = J(w_o, w_o)$.*

Proof. For $\sigma < 1$, Result 1 gives that $J(w_n, w_n) < J(w_o, w_o)$ and for $\sigma = 1$ $J(w_n, w_n) = J(w_o, w_o)$.

The proof strategy is to analyze the exit condition. The difficulty arises because in steady state the relative prices that restaurants face when they enter differs from the relative prices they face when they exit because some of the cost of capital is sunk. A restaurant exits when MC=MB. So consider the exit condition, equation (8), for both the new entrants:

$$e^{-\delta J(w_n, w_n)} y_0 P_n = r\eta p^k k_n + w^h h_n + p^m m_n + w_n l_n, \tag{A15}$$

and the incumbents:

$$e^{-\delta J(w_o, w_n)} y_0 P_n = r\eta p^k k_o + w^h h_o + p^m m_o + w_n l_o. \tag{A16}$$

Rearrange these expressions so that the left hand sides are equal:

$$y_0 P_n = \left(r\eta p^k k_n + w^h h_n + p^m m_n + w_n l_n \right) e^{\delta J(w_n, w_n)} \tag{A17}$$

$$y_0 P_n = \left(r\eta p^k k_o + w^h h_o + p^m m_o + w_n l_o \right) e^{\delta J(w_o, w_n)}. \tag{A18}$$

Set them equal and rearrange:

$$\frac{\left(r\eta p^k k_n + w^h h_n + p^m m_n + w_n l_n\right)}{\left(r\eta p^k k_o + w^h h_o + p^m m_o + w_n l_o\right)} = e^{\delta J(w_o, w_n)} e^{-\delta J(w_n, w_n)}. \tag{A19}$$

Note that $J(w_n, w_n) \leq J(w_o, w_o)$ for $\sigma \leq 1$ so that showing that the left hand side is less than 1 proves what we want. Hence, we would like to show:

$$\left(r\eta p^k k_o + w^h h_o + p^m m_o + w_n l_o \right) > \left(r\eta p^k k_n + w^h h_n + p^m m_n + w_n l_n \right). \tag{A20}$$

To do so, note that input bundles (k_o, h_o, m_o, l_o) and (k_n, h_n, m_n, l_n) are both on the y_0-isoquant (both produce y_0 in a brand new restaurant). Cost minimization implies that:

$$\left(q_n^k k_o + q_n^h h_o + q_n^m m_o + q_n^w l_o \right) > \left(q_n^k k_n + q_n^h h_n + q_n^m m_n + q_n^w l_n \right). \tag{A21}$$

Converting to flow prices by multiplying by $\frac{r}{1-e^{-rJ(w_n,w_n)}}$:

$$\left(\frac{1-\eta e^{-rJ(w_n,w_n)}}{\eta(1-e^{-rJ(w_n,w_n)})} rp^k \eta k_o + w^h h_o + p^m m_o + w_n l_o\right) > \left(\frac{1-\eta e^{-rJ(w_n,w_n)}}{\eta(1-e^{-rJ(w_n,w_n)})} rp^k \eta k_n + w^h h_n + p^m m_n + w_n l_n\right) \tag{A22}$$

$$\left(\left(\frac{1-\eta}{\eta(1-e^{-rJ(w_n,w_n)})}+1\right) rp^k \eta k_o + w^h h_o + p^m m_o + w_n l_o\right)$$
$$> \left(\left(\frac{1-\eta}{\eta(1-e^{-rJ(w_n,w_n)})}+1\right) rp^k \eta k_n + w^h h_n + p^m m_n + w_n l_n\right) \tag{A23}$$

$$\left(\left(\frac{(1-\eta)r\eta p^k}{\eta(1-e^{-rJ(w_n,w_n)})}\right)(k_o-k_n) + rp^k \eta k_o + w^h h_o + p^m m_o + w_n l_o\right) > \left(rp^k \eta k_n + w^h h_n + p^m m_n + w_n l_n\right). \tag{A24}$$

Note that if $\left(\frac{(1-\eta)r\eta p^k}{\eta(1-e^{-rJ(w_n,w_n)})}\right)(k_o-k_n) \leq 0$, then Equation (A20) holds. Since $\frac{(1-\eta)r\eta p^k}{\eta(1-e^{-rJ(w_n,w_n)})} > 0$, we need that $k_o \leq k_n$: following a minimum wage hike, the usage of capital increases. This is true by assumption. This completes the proof. ∎

When would a minimum wage *increase* lead to a *decrease* in the use of capital and our high-level sufficient condition to fail? This cannot happen when $\sigma = 1$, because in this case $\frac{k_n}{k_o} = \left(\frac{w_n}{w_o}\right)^{1-\alpha}$ and the sufficient condition is always satisfied. This might happen if the exit age is incredibly responsive to the minimum wage (i.e. if $\frac{\partial 1-e^{-rJ}}{\partial w}\frac{w}{1-e^{-rJ}} > 1$). Then it is possible that capital use declines. The central difficulty in ruling out this case is that we cannot solve for J in closed form so it is hard to bound its responsiveness to w.

Condition for the product price to jump immediately to its new steady state level

Under the assumption that the product price immediately jumps to its new steady state level, the output of the exiting firms is:

$$\int_{J(w_o,w_n)}^{J(w_o,w_o)} e^{-\delta j} y_0 f_o dj = \frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0. \tag{A25}$$

Under this assumption, the change in market quantity is $Q_o - Q_n$, where the market quantity is a function of the product price.

What has to happen for the exit spike to be large enough to accommodate the hypothesized decline in market quantity? The relevant inequality is:

$$\frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0 \geq Q_o - Q_n. \tag{A26}$$

That is, the exit spike has to be (weakly) larger than the change in market quantity. This leaves room for there to be an entry spike as well (if the inequality is strict).

Now we manipulate (A26) to ask what has to be true for the inequality to be satisfied. Divide both sides by Q_o, where $Q_o = \frac{f_o y_0}{\delta}(1 - e^{-\delta J(w_o,w_o)})$:

$$\frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{1 - e^{-\delta J(w_o,w_o)}} \geq \frac{Q_o - Q_n}{Q_o}.$$

Multiply through by $\frac{e^{\delta J(w_o,w_o)}}{e^{\delta J(w_o,w_o)}}$ on the left hand side and simplify:

$$\frac{e^{\delta J(w_o,w_o)-\delta J(w_o,w_n)} - e^{\delta J(w_o,w_o)-\delta J(w_o,w_o)}}{e^{\delta J(w_o,w_o)} - e^{\delta J(w_o,w_o)-\delta J(w_o,w_o)}} \geq \frac{Q_o - Q_n}{Q_o} \tag{A27}$$

$$\frac{e^{\delta J(w_o,w_o)-\delta J(w_o,w_n)} - 1}{e^{\delta J(w_o,w_o)} - 1} \geq \frac{Q_o - Q_n}{Q_o}. \tag{A28}$$

Result 2 shows that $J(w_o, w_o) > J(w_o, w_n)$ so that the numerator is positive.

The condition for the product price to jump immediately to the new steady state level is:

$$\frac{e^{\delta J(w_o,w_o)-\delta J(w_o,w_n)} - 1}{e^{\delta J(w_o,w_o)} - 1} \geq \frac{Q_o - Q_n}{Q_o}. \tag{A29}$$

Or, dividing by the right hand side, multiplying through by the denominator on the left hand side, adding one to both sides, and taking logs, the condition can be rewritten as:

$$\ln\left\{\frac{e^{\delta J(w_o,w_o)-\delta J(w_o,w_n)} - 1}{\frac{Q_o - Q_n}{Q_o}} + 1\right\} \geq \delta J(w_o, w_o). \tag{A30}$$

Appendix E: Entry and Exit Dynamics Following a Minimum Wage Hike

Exit Dynamics

In the old steady state the number of firms that exit in a period interval Δ is:

$$\Delta f_o \tag{A31}$$

and the implied output of these exiting firms is:

$$\Delta e^{-\delta J(w_o,w_o)} f_o y_0. \tag{A32}$$

The minimum wage increase results in an exit of firms with ages between $J(w_o, w_n)$ and $J(w_o, w_o)$. So the number of firms exiting is:

$$\int_{J(w_o,w_n)}^{J(w_o,w_o)} f_o dj = f_o(J(w_o, w_o) - J(w_o, w_n)). \tag{A33}$$

The total output of exiting firms is:

$$\int_{J(w_o,w_n)}^{J(w_o,w_o)} e^{-\delta j} y_0 f_o dj = \frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0. \tag{A34}$$

Appendix D showed that when $\sigma \leq 1$ then $J(w_o, w_n) < J(w_n, w_n) < J(w_o, w_o)$. In the interval $(t_n, t_n + J(w_o, w_n)]$ only the old firms exit. Hence, the number of firms exiting is:

$$\Delta f_o \tag{A35}$$

and the output that exits is:

$$\Delta f_o e^{-\delta J(w_o,w_n)} y_0. \tag{A36}$$

After time $t_n + J(w_o, w_n)$, all of the old firms have exited. In the interval $(t_n + J(w_o, w_n), t_n + J(w_n, w_n))$, the old firms do not exit, nor do the new firms. Table A2 summarizes this discussion.

Table A2: **Exit dynamics, with a permanent minimum wage increase at t_n**

Time	Number	Quantity	Eqn. #
$(-\infty, t_n)$	Δf_o	$\Delta e^{-\delta J(w_o,w_o)} f_o y_0$	A31, A32
t_n	$f_o(J(w_o,w_o) - J(w_o,w_n))$	$\frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0$	A33, A34
$(t_n, t_n + J(w_o,w_n))$	Δf_o	$\Delta e^{-\delta J(w_o,w_n)} f_o y_0$	A35, A36
$[t_n + J(w^o,w_n), t_n + J(w_n,w_n)]$	0	0	

Note: This table summarizes results in equations (A31)-(A36). A Δ indicates that the pdf is bounded so that instantaneously there is no entry/exit. The Δ is a time interval.

Entry Dynamics

In the old steady state the number of entrants is:

$$\Delta f_o \tag{A37}$$

and the output of entrants is

$$\Delta f_o y_0. \tag{A38}$$

At implementation of the minimum wage hike, the market quantity declines from Q_o to Q_n and remains constant thereafter. Hence, the entry at implementation must accommodate this decline. Using this fact and equation (A34), the output that is replaced is:

$$\frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0 + (Q_n - Q_o). \tag{A39}$$

The fact that the output of new firms is y_0 along with equation (A39) implies that the number of entrants is:

$$\frac{\frac{e^{-\delta J(w_o,w_n)} - e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0 + (Q_n - Q_o)}{y_0}. \tag{A40}$$

Over the time interval $(t_n, t_n + J(w_o,w_n))$, Q_n remains constant, and the amount of exiting

Table A3: **Entry dynamics, with a permanent minimum wage increase at t_n**

Time	Number	Quantity	Eqn. #
$(-\infty, t_n)$	Δf_o	$\Delta f_o y_0$	A37, A38
t_n	$\frac{\frac{e^{-\delta J(w_o,w_n)}-e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0 + (Q_n - Q_o)}{y_0}$	$\frac{\frac{e^{-\delta J(w_o,w_n)}-e^{-\delta J(w_o,w_o)}}{\delta} f_o y_0 + (Q_n - Q_o)}{y_0}$	A40, A39
$(t_n, t_n + J(w_o, w_n))$	$\Delta \frac{\left\{e^{-\delta J(w_o,w_n)} f_o y_0 + \delta Q_n\right\}}{y_0}$	$\Delta \left\{e^{-\delta J(w_o,w_n)} f_o y_0 + \delta Q_n\right\}$	A42, A41
$[t_n + J(w_o, w_n),$ $t_n + J(w_n, w_n)]$	$\Delta \frac{\delta Q_n}{y_0}$	$\Delta \delta Q_n$	A44, A43

Note: This table summarizes results in equations (A37)-(A44). A Δ indicates that the pdf is bounded so that instantaneously there is no entry/exit. The Δ is a time interval.

and depreciating output is given by

$$\Delta \left\{ e^{-\delta J(w_o,w_n)} f_o y_0 + \delta Q_n \right\} \tag{A41}$$

so that the entering number is

$$\frac{\Delta \left\{ e^{-\delta J(w_o,w_n)} f_o y_0 + \delta Q_n \right\}}{y_0}. \tag{A42}$$

Finally, in $(t_n + J(w_o, w_n), t_n + J(w_n, w_n))$, there is no exit and thus entry just replaces the depreciation. Output is then:

$$\Delta \delta Q_n \tag{A43}$$

and the resulting number of new entrants is

$$\Delta \frac{\delta Q_n}{y_0}. \tag{A44}$$

Table A3 summarizes this discussion.

Appendix F: Additional Tables

Table A4: QCEW Sample Construction

	Exit sample	Entry sample
A. Limited service, minimum employee size is 1		
All establishments in counties with > 10 establishments in final sample	61,595	56,225
delete establishments not passing size threshold	51,297	50,253
and delete breakouts/consolidations (Final sample)	40,739	39,769
B. Limited service, minimum employee size is 15		
All establishments in counties with > 10 establishments in final sample	60,375	55,226
delete establishments not passing size threshold	23,158	23,473
and delete breakouts/consolidations (Final sample)	16,191	16,513
C. Full service, minimum employee size is 15		
All establishments in counties with > 10 establishments in final sample	54,925	50,122
delete establishments not passing size threshold	21,484	22,081
and delete breakouts/consolidations (Final sample)	18,184	18,529

Note: This table reports how three of our key samples were constructed. In the first row of each panel (labeled "all establishments in counties..."), we report the total number of establishments in our exit and entry samples. To appear in our sample, BLS confidentiality requires that counties ultimately have a minimum number of establishments. The difference in samples between panels A and B reflect the counties that meet this minimum number of establishments with at least 1 employee but not with at least 15 employees. Recall to be in the exit sample, an establishment must meet minimum employment requirements at time $t-1$ but may or may not remain open at time t. Analogously, to be included in the entry sample, an establishment must meet minimum employment requirements at time t but may or may not be open at time $t-1$. The next row in each panel deletes establishments that do not meet the minimum size threshold (of 1 in panel A and 15 in panels B and C). Finally, the third row (labeled "and delete breakouts/consolidations") is our final sample after additionally removing establishments that are part of a QCEW breakout or consolidation.

Table A5: Descriptive Statistics, QCEW

			Average size of establishment	
	Exit rate	Entry rate	Exit sample	Entry sample
Limited service restaurants	0.057	0.087	31.7	31.7
Chains	0.033	0.071	31.6	31.2
Non-chains	0.075	0.099	31.8	32.0
Full service restaurants	0.068	0.095	42.6	43.3

Note: This table reports the exit and entry rates, as well as the average employment size, for limited and full service restaurants with a minimum employment threshold of 15. The average size of limited service restaurants in the exit sample with at least 1 employee is 16.7 (all), 25.7 (chains), and 13.9 (non-chains).