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Earnings, EITC, and Employment Responses to a $15 Minimum Wage: Will Low-Income Workers Be Better Off?

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Abstract

The District of Columbia will increase its minimum wage to $15 per hour in 2020. The city also provides a local refundable earned income tax credit (EITC) equal to 40% of the federal EITC. Using a computable general equilibrium model, the authors estimate the economic impact of the $15 wage policy. They also use a tax policy microsimulation model to estimate how the city's EITC interacts with a higher minimum wage. Overall, the authors find that the higher minimum wage will produce significant income gains for most of the city's low-wage workers, with relatively few job losses. Additionally, they forecast that most city EITC recipients will receive a lower EITC, but higher earnings more than offset the reduced tax credit. The model predicts that this policy change would largely be funded by higher consumer prices, lower firm profits, and higher business productivity. These predictions are subject to important caveats, including a local labor market that is likely inadequately characterized in a model assuming perfect competition. Economic policy makers should therefore use such modeling approaches as a powerful but ultimately imperfect tool.

Keywords

minimum wage, EITC, general equilibrium, low-income workers, policy simulation

In recent years, an increasing number of state and local policy makers have responded to concerns over stagnant wages and rising inequality by enacting minimum wage increases above the federally mandated level of $7.25 per hour. Among these, the District of Columbia stands out as the first to increase the hourly minimum wage for all city workers, in annual increments, to $15 by 2020. Predating this policy change, the city also enacted an earned income tax credit (EITC) for low-income working residents. As a package, the city's EITC and $15 Minimum Wage Policy ($15 MWP) represent one of the most aggressive local labor-market policy interventions for low-income workers in the nation.

This study analyzes the economic impact of the $15 MWP for the District of Columbia, including how the higher minimum wage interacts with receipt of the federal and local EITC. We use a computable general equilibrium (CGE) model to estimate the income and employment effects of the city's $15 MWP after full implementation in 2021, and a microsimulation model to estimate how federal and local EITC levels for city residents are likely to respond to the $15 MWP in 2021. While the increase in the city's minimum wage affects nearly everyone, to varying degrees, within the regional economy—if even only through higher prices for select goods and services—this analysis focuses primarily on city residents potentially affected by higher wages or employment shocks.

We forecast that the city's $15 MWP will raise the incomes of 15.5% of all working city residents—approximately 61,000 people—by $3,160 (a 16.5% average increase) in 2021. Approximately 1,074, or 1.8%, of low-wage city residents (earning $18 per hour or less) will experience job loss as a result of the policy change, despite overall job growth in the city. This estimated disemployment will increase to approximately 1,860, or 3.1%, of low-wage city residents in 2026. We also find that over 63% of working city residents likely affected by the higher minimum wage will be EITC recipients. While nearly all EITC filers are forecast to experience lowered federal and local EITC as a result of higher post-$15 MWP annual earnings, higher earnings will combine for a net-income increase, on average. The minimum wage is predicted to disproportionately affect workers in the commercial retail, health care and social assistance, accommodation, and food service industries. We also predict that the policy will be supported by a combination of higher consumer prices, lower firm profits, and higher business productivity.

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Background on Minimum Wage Research

While expansive, there is mixed evidence on the overall economic and employment effects of minimum wages. Here, we provide only a brief background on minimum wage research. See Borjas (2016), Neumark (2017), Neumark and Wascher (2006), and Wolfson and Belman (2016) for a more comprehensive discussion and summary of minimum wage policies and their economic impacts.

Among the subset of minimum wage studies we surveyed, minimum wage employment elasticities ranged from −0.20 to +0.10. Among these, Neumark and Wascher (2007) reported elasticities in the range of −0.10 to −0.20 for teens and −0.15 to −0.20 for the youth population overall. Sabia, Burkhauser, and Hansen (2012) estimated elasticities of −0.13 for workers with a high school diploma, while finding that workers between 25 and 29 years old with at least a bachelor's degree have employment elasticities of +0.10. Addison, Blackburn, and Cotti (2009, 2012), Card and Krueger (2000), and Dube, Lester, and Reich (2010) estimated elasticities near zero for restaurant and fast food workers.

Some critics of local minimum wages suggested it is poorly targeted at raising incomes among the working poor (Sabia, 2014), preferring some combination of human capital development, refundable EITCs, or direct income transfers (Neumark, 2004). Others argued that subgroups with already low levels of employment and labor force attachment could be harmed by policies that raise hiring and labor costs (Holzer, 2015). Standard neoclassical economic theory characterizes the imposition of a minimum wage within a perfectly competitive labor market, wherein the policy establishes an artificially high-wage floor above the local market equilibrium. Higher wages increase the quantity of labor supplied while also reducing the quantity of labor demanded, resulting in unemployment. Relatively, recent studies finding unemployment consequences from MWP interventions include Neumark and Wascher (2007) and Sabia et al. (2012).

These concerns notwithstanding, District of Columbia and 29 states have enacted minimum wages above the federal level (Congressional Research Service, 2019). The contemporary evidence base—on which policy makers ostensibly rely to guide their decision making—lacks consensus on the employment effects (Neumark, 2017).

This lack of consensus stems from several empirical studies that find little or no significant negative employment impacts from minimum wages (Addison et al., 2009, 2012; Card & Krueger, 1994; Dube et al., 2010), along with increased family incomes (Bernstein & Shierholz, 2014; Rinz & Voorheis, 2018) and reductions in poverty (Dube, 2017). This can occur within a standard neoclassical framework, insofar as businesses pass costs onto consumers through higher prices and customers exhibit inelastic consumption preferences with high discretionary income. This inelastic behavior is a feature of many U.S. cities that have implemented such policy changes (MaCurdy, 2015), though these local markets are likely more monopsonistic than perfectly competitive.

Ultimately, methodological differences may be yielding diverging employment effects throughout the literature (Kuehn, 2014, 2017). Specifically, regression-based approaches using within-region variation that do not compare areas "treated" by a minimum wage increase with otherwise similar localities unaffected by a minimum wage shock appear to be more likely to predict employment reductions from the minimum wage. Conversely, studies that match on similar counties tend to find that higher minimum wages have not reduced employment (e.g., Dube et al., 2010). For example, partial equilibrium analyses by Nichols and Schwabish (2014) and Acs, Wheaton, Enchautegui, and Nichols (2014) assessed the 2014 District of Columbia minimum wage relative to the 1993 minimum wage increase of similar magnitude and found minimal historical evidence of lower employment levels.

The underlying mechanisms generating zero net disemployment are posited to include (a) efficiency wages, as well as insights into the features of local labor markets—increasingly characterized as (b) monopsonistic rather than perfectly competitive (Council of Economic Advisers, 2016; Furman & Orszag, 2015; Manning, 2003). Efficiency wage theory holds that workers respond positively to higher compensation and raise their own productivity, reducing turnover costs. Monopsony, wherein firms exert market power and set factor input prices with varying levels of productivity, can lead to equilibrium conditions in which minimum wages generate net-zero employment changes—reflecting a firm response wherein wages are raised to the mandated level or marginally above—within a marketplace with search frictions and lacking a wide range of employment alternatives for workers (Cengiz, Dube, Lindner, & Zipperer, 2017; Council of Economic Advisers, 2016).

Simulation models, such as Regional Economic Models, Inc. (REMI), do not reflect these mechanisms, relying instead on neoclassical microeconomic assumptions; they are biased toward predicting employment losses from minimum wage increases. Taken together with evidence of substantial earnings gains from minimum wage increases occurring across the nation, higher minimum wage policies may be beneficial for workers and should be evaluated on a case-by-case basis. For economic policy makers nationwide, such case-by-case assessments should include careful consideration of the local labor market's characteristics.

Within a large literature on minimum wages, relatively few studies assess recent, relatively large local minimum wage changes in U.S. cities or jurisdictions (Neumark, 2017). In one such study, Jardim et al. (2017) provided new evidence on a minimum wage expansion in Seattle, WA similar in magnitude to that occurring in the District of Columbia.

They found mixed results from the city's minimum wage expansion from roughly $9.50 to $13; namely, that earnings decline—through fewer hours worked—while employment participation remains unchanged.

Ultimately, our study uses a general equilibrium approach to estimate the impact of a policy change—here, a higher minimum wage—within a local labor market over time. Other forecasting studies on minimum wages include Reich et al. (2016), who used the IMPLAN model and found minimal employment consequences (0.3% of projected 2019 employment) from higher minimum wages—annual pay would increase 17.8%, or about $3,000, on average, in San Jose, California. Another model, the Urban Institute's DYNASIM4, has been used to examine how a minimum wage increase could improve economic security during retirement (Cosic, Johnson, & Smith, 2018). Ours is also among the few studies (Neumark & Wascher, 2001, 2011) to forecast the potential impact of the minimum wage alongside the EITC in the District of Columbia. This is especially relevant, given that the District of Columbia currently provides the nation's largest local supplement to the federal EITC, a refundable 40% of federal EITC received.

Motivating the CGE Approach

Between 2014 and 2016, when the District of Columbia increased its minimum wage from $8.25 to $11.50 ($11.50 MWP), local policy makers began debating whether to implement a $15 MWP. In 2014, no state or jurisdiction in the country had enacted such a policy and several questions remained unanswered; among these, we focus on three. First, what would be the order of magnitude for estimated job losses, if any, under the proposal? Second, to what extent would this policy adversely affect city businesses relative to their competitors in neighboring jurisdictions of Maryland and Virginia? Third, how would the interplay between the $15 MWP and both the federal and local EITC affect the economic well-being of low-wage residents?[1]

The potential wide-ranging economic consequences of the $15 MWP motivated the use of a CGE model to forecast the citywide short- and long-run economic responses. CGE models are often used to help inform decision making by facilitating the analysis of economic impacts from a substantive policy change or economic shock. The models aim to reproduce the structure of an entire economy through a system of mathematical equations that characterize economic transactions in a realistic manner, using local economic data. All the model equations are derived from economic theory and are solved simultaneously to find economy-wide equilibria in which, for some set of prices, the quantities of supply and demand are equal in every market. Thus, the model operates in the spirit of a circular flow of income and spending in the local economy during the past full year in which data are available. The models rely on elasticity parameters derived from prior economic research that express average industry- and sector-specific producer and consumer responses—elasticities—to changes in prices and income (Burfisher, 2017; Treyz & Stevens, 1985; Wing, 2004).

Some CGE models solve for a one-time period and assume economic behavior depends only on the present and the past. For these models, the adjustment process is not explicitly represented in the model. Other models, however, attempt to incorporate reciprocal causation or behavioral feedback loops of economic agents that derive from an adjustment process and the future state of the economy itself. This class of CGE models, dynamic general equilibrium models, traces each economic variable through time, distinguishing between short- and long-run equilibrium and solving for future time periods simultaneously.

Along with the aforementioned strengths, CGE models are also considered by many to be "black boxes." This concern stems, at least in part, from the fact that these models have a significant degree of built-in rigidity, are premised on hard-coded a priori elasticities, and lack standard errors for particular model estimates. For example, Mitra-Kahn (2008) argued that CGE model builders could assuage many concerns by revealing elasticity values used in their models, as well as how these values are derived. The complexity of CGE models and the relatively unknown nature of some parameters often makes it difficult to trace results to specific features of their databases, input parameters, or algebraic structure (Wing, 2004). While REMI incorporates all current District of Columbia area macroeconomic data, it cannot run historical forecasts or control for historical variables.[2] We are thus unable to control for the range of prior economic factors, preventing us from using REMI to assess previous minimum wage increases.

CGE models aim to fully account for interactions between key variables of interest and the rest of the economy; this requires solving for equilibrium across every market in the local economy simultaneously, accounting for constraints that apply to the various factors of production and their movement across sectors. In doing so, we lose the relative transparency of partial equilibrium models.

Although CGE models yielding specific point estimates for one or two select economic outcomes should be viewed cautiously, these models can identify an array of economic responses to a large event or policy change occurring over time, thereby helping to identify winners and losers of policy changes. Simply put, CGE models, as well as other policy simulation models, are economic tools that can complement partial equilibrium models and other statistical analyses.[3]

Data

Employment Data

To estimate the number and distribution of low-wage jobs affected by the city's $15 MWP by industry, we begin by using Bureau of Labor Statistics (BLS) Occupational Employment

Table 1. Forecasted Jobs Impact of the District of Columbia $15 MWP, by Occupation.

	Jobs by occupations and by 2014 wage rate levels						
Two-digit SOC occupation	$8.25: 2014 Min. wage	$8.25-$11.50	$11.50-$12.50	$12.50-$13.50	$13.50-$15.00	$15.00-$18.00	Total jobs
Food preparation and serving related occupation	4,040	32,076	4,062	2,588	2,394	3,268	48,428
Office and administrative support	2,303	3,874	2,008	2,480	4,588	11,440	26,692
Building and grounds cleaning and maintenance	800	3,773	2,092	2,381	3,642	5,365	18,054
Sales and related	1,875	8,842	2,552	1,669	1,399	1,385	17,721
Personal care and service	674	4,234	1,534	1,090	1,107	1,523	10,161
Protective service	556	1,179	675	848	1,617	4,030	8,904
Healthcare support	339	2,673	1,300	1,167	1,368	1,899	8,746
Transportation and material moving	390	3,151	306	350	600	1,422	6,219
Community and social services	320	400	265	360	714	1,653	3,713
Education, training, and library	535	311	219	270	485	1,654	3,474
Construction and extraction	126	265	181	230	470	1,363	2,635
Arts, design, entertainment, sports, and media	921	40	67	78	181	936	2,222
Business and financial operations	808	—	—	1	34	901	1,745
Health care practitioners and technical	463	158	85	104	195	670	1,676
Legal	1,118	—	—	—	—	237	1,355
Life, physical, and social science	217	166	99	127	244	727	1,580
Installation, maintenance, and repair	149	77	119	145	277	746	1,514
Production	207	300	119	110	144	292	1,171
Management	390	—	—	—	—	235	624
Computer and mathematical	219	—	—	49	89	294	650
Architecture and engineering	42	—	3	3	6	81	135
Farming, fishing, and forestry	—	—	—	—	—	—	—
Total	16,492	61,518	15,686	14,049	19,554	40,120	167,419

Note. MWP = Minimum Wage Policy; SOC = Standard Occupational Classification; OES = Occupational Employment Statistics. This table is an interpolation of 2014 OES data that allow for the creation of a continuous wage distribution by occupation. The OES data provide a snapshot of the median wages at the 10th, 25th, 50th, 75th, and 90th percentiles. These data include all part-time and full-time workers who are paid wages and salaries (including bonuses and tips), but do not cover self-employed workers, sole proprietors, household workers, or unpaid family workers.
Source. OES and authors' calculations.

Statistics (OES) survey data and the U.S. Census Bureau's American Community Survey (ACS). The OES program produces hourly and annual employment and wage estimates for over 800 occupations at the national and metropolitan level, while the ACS provides information on place of work and workers' state of residency. Data used in this study are from the OES May 2014 estimates for District of Columbia, when the District of Columbia minimum wage was $8.25.

Among the roughly 800 occupations in the District of Columbia, we identify the number of jobs that are likely affected from raising the minimum wage to $15. We estimate that, in 2014, 127,299 jobs in the city paid $15 per hour or less, accounting for about 18.8% of the district's overall employment base. The OES data include all part-time and full-time workers who are paid a wage or salary, but do not cover self-employed workers, sole proprietors, household workers, or unpaid family workers.[4]

Studies have shown that employers typically increase wages among workers earning slightly above a new minimum wage to reduce wage compression (Lopresti & Mumford, 2015). We therefore include jobs with wage rates slightly above the new $15 minimum wage rate to allow for these spillover effects. We allow for a $3 spillover, which arguably helps maintain within-firm wage differentials commensurate with differences in experience, seniority, educational attainment, and productivity. The distribution of the resulting 167,419 city jobs affected by the $15 MWP is shown in Table 1, according to their two-digit Standard Occupational Classification (SOC) occupations. We also calculated the wage distribution for 95 three-digit SOC occupations and used this more precise distribution as an input into the CGE model.

Industry-Level Wage and Salary Data

The occupational impacts from Table 1 are converted to comparable industry impacts using the National Industry-Occupation Employment Matrix developed by BLS to depict the occupational employment structure of different industries. For each industry, it provides the percentage of total

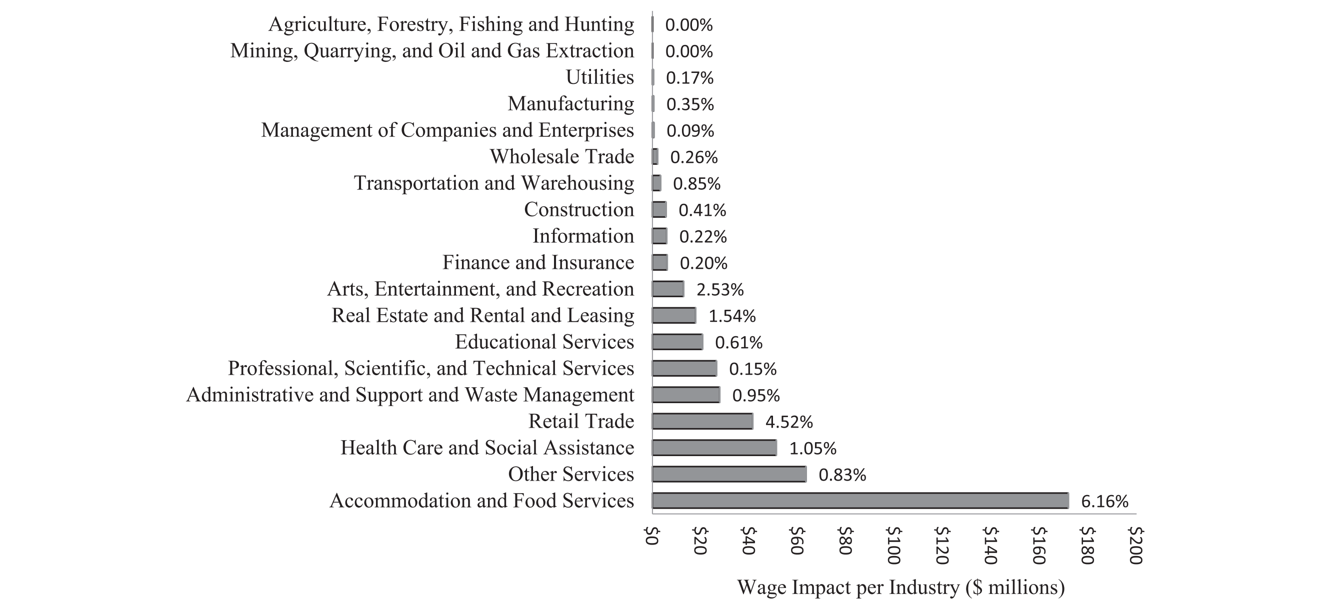

Figure 1. Gross impact of minimum wage increase by industry (million $s).
Source. Authors' calculations using 2014 Bureau of Labor Statistics Occupational Employment and Wage Estimates for the District of Columbia, converted to industry information using National Industry-Occupation Matrix.

Table 2. Forecasted Impact of the District of Columbia $15 MWP on Wages and Salaries in 2021 (Million $s).

	All city employees	City residents
Total private wages and salaries ($11.50 MWP—baseline)	$53,056.0	$21,222.0
Total private wages and salaries ($15 MWP—policy simulation)	$53,549.0	$21,419.0
Estimated change in wages and salaries (includes spillover)	$493.2	$197.3
Estimated percentage increase in city wages and salaries	0.93	0.93

Note. MWP = Minimum Wage Policy; ACS = American Community Survey.
Source. Authors' calculations derived from Bureau of Economic Analysis and ACS data.

employment accounted for by each detailed occupation. Using the matrix, we estimate the 2014 total wages for every job with an estimated hourly wage of no more than $18 in terms of the 66 private nonfarm NAICS industries. Figure 1 depicts the distribution of higher 2017 city minimum wages across industries. It shows that commercial retail, health care and social assistance, other services, and the accommodation and food service industries are forecast to absorb over 70% of the total wage impact.

We estimate the total wages among this worker population for both the $11.50 MWP (baseline) and the $15 MWP (policy simulation) annually until 2021, finding that the increase in total wages and salaries in the city in 2021 is $493.2 million, an approximately 1% increase in the city's total wages and salaries (Table 2). The city will reach the statutory $15 minimum wage in 2020, though our short-term analysis will be centered on 2021, 1 year after full implementation of the policy. Our long-term analysis will be centered on 2026, 5 years after full implementation.

Similar to some other large cities, most of the District of Columbia's workforce is composed of noncity residents. Based on ACS data, city residents held approximately 40% of city jobs with hourly wages of $18 or below. The remaining jobs were held by noncity residents, primarily from the bordering states of Maryland and Virginia. Table 3 shows the total estimated number of jobs in the city and the total number of jobs held by city residents affected by the $15 MWP, where 40% of each range represents the jobs held by city residents. We thus assume that city residents are distributed relatively evenly across the low-wage employment market.

This enables us to quantify one of the two primary policy shocks used in the model. On the household income side, we introduce gradual annual positive shocks beginning in 2017, increasing to a total shock to city income in 2021 of $493 million. This represents the estimated additional wage and salary income resulting from the $15 MWP for the 167,419 jobs paying $18 per hour or less in 2017 when the policy goes into effect. On the production side of the economy, we

Table 3. Forecasted Jobs Impact of District of Columbia $15 MWP for Resident City Workers in 2017.

Estimated wage rates	All city jobs	City jobs held by city residents
Up to $8.25 minimum wage	16,492	6,597
$8.26-$11.50	61,518	24,607
$11.51-$12.50	15,686	6,274
$12.51-$13.50	14,049	5,620
$13.51-$15.00	19,554	7,822
Subtotal (wage rate up to $15/hour)	127,299	50,920
Wage rate between $15 and $18 (spillover)	40,120	16,048
Total	167,419	66,968

Note. MWP = Minimum Wage Policy; ACS = American Community Survey; OES = Occupational Employment Statistics.
Source. Authors' calculations derived from OES and ACS data.

introduce gradual annual negative shocks beginning in 2017, culminating in a $528 million shock—equivalent to the previously estimated $493 million in higher earnings plus payroll taxes—to labor costs for city businesses in 2021.

The CGE Model

The CGE model used for this analysis is the REMI PI+.[5] It models the regional economy of the District of Columbia and six surrounding metropolitan areas and their 66 three-digit private, nonfarm NAICS industries. The REMI PI+ model solves for local market general equilibria through price adjustments in the regional economy annually, while simultaneously modeling behavioral changes (i.e., labor supply, migration, and commuting patterns) over a longer time period in response to an initial economic or policy shock.[6] The model uses local regional economy time series data and local coefficients, including labor productivity parameters and housing price elasticities, yielding District-of-Columbia-specific response patterns to shocks in our model (Treyz, Rickman, & Gang, 1991; Treyz & Stevens, 1985). REMI, in contrast to input–output models such as IMPLAN and RIMS II, allows for changes in relative factor costs such as changes in wages or the cost of capital. If these variables are held constant, then REMI would more closely approximate a traditional input–output model.

The REMI model uses structural equations to formulate policy-relevant simulations, though at the cost of predictive ability (Cassing & Giarratani, 1992). Using four major approaches to economic analysis—(a) an input–output matrix, (b) econometric modeling for parameter estimation, (c) economic geography, and (d) general equilibrium analysis—the model allows for annual policy responses and approximates adjustments occurring among the regional economy's consumers and producers. Partridge and Rickman (1998) argued that because REMI PI+ does not model consumer utility maximization and firm profit maximization at the regional level it is not a classical bottom-up CGE model. However, given that it contains many CGE features, as noted above, we refer to REMI PI+ as a CGE model.

In 2017, we allow for two primary exogenous shocks: (a) annual increases in wage income for city workers and (b) annual increases in labor costs for city businesses. These two shocks initially create disequilibrium in the district's economy, but the economy gradually moves to regain equilibrium over time and the model catalogues these changes. Movement toward a new equilibrium involves changes in employment, income, consumption, and prices, as well as trade flows in and out of the city to neighboring states. These dynamic interdependencies are summarized in five major sets of economic measures: (a) output and demand, (b) labor and capital demand, (c) population and labor supply, (d) compensation, prices, and costs, and (e) market shares (REMI, 2017).

The labor and capital demand subcomponent of the model is central to our study. The use of labor relative to other factors is determined by the cost of labor compared with the cost of other factors, such as capital and fuel. In the model, the substitution between labor, capital, and fuel is based on a Cobb–Douglas production function, accounting for the interplay between capital (e.g., operating space, computer equipment, and work-related tools) and labor in driving overall production and revenue. As the cost of labor increases per the $15 MWP, demand for labor (with other factors held constant) is assumed to fall according to standard economic theory. Changes in labor demand are controlled by industry-specific labor intensities. The rates of substitution between capital and labor are derived from empirical studies that consider wages and commuting patterns (Weisbrod, Vary, & Treyz, 2001). REMI's unit of measurement for employment is in terms of full-time equivalent and does not distinguish between part-time and full-time workers.

Modeling Five Scenarios

The $15 MWP represents a sizable exogenous shock to the city's economy. To assess the sensitivity of forecasted employment impacts to our assumptions, we produce five forecast scenarios for the $15 MWP. We simulate the economic impacts of each scenario under the new MWP relative to the city's baseline $11.50 MWP.

Table 4. Scenarios and Underlying Assumptions for Model Simulations.

Scenario	Description	Assumption(s)	Economic shocks
#1 (Base case)	Minimal workers affected, no offsetting gains	Only workers earning less than $15 an hour in 2017 will benefit	A: $387 Million increase workers' wages B: $417 Million increase in business costs
#2 (Worst case)	Base case + spillover (no offsetting gains)	Scenario 1 plus workers earning $15-$18 in 2017 will also benefit	A: $493 Million increase workers' wages B: $528 Million increase in business costs
# 3 (Productivity case)	Base + spillover + productivity	Scenario 2 plus businesses offset 30% of the increase in costs due to increased productivity	A: $493 Million increase workers' wages B: $372 Million increase in business costs
# 4 (Most likely case)	Base + spillover + productivity + consumption	Scenario 3 plus wage gainers will spend their additional income on consumption	A: $493 Million increase workers' wages B: $50 Million, or 0.15%, extra demand for consumption in District of Columbia C: $372 Million increase in business costs
# 5 (Best case)	Base + spillover + consumption + efficiency wage	Scenario 4 plus offset 75% of the increase in costs due to increased productivity and other efficiencies	A: $493 Million increase workers' wages B: $50 Million, or 0.15%, extra demand for consumption in District of Columbia C: $80 Million increase in business costs

Note. The increase in business costs of $528 million in Scenario 2 factors in the payroll tax that businesses pay on the additional $493 million in wages. The Regional Economic Models, Inc. model assumes a certain percentage of additional wage income to be allocated to consumption based on a typical District of Columbia worker, as assumed (but not shown) in Scenarios 1, 2, and 3. However, since low-wage workers have different consumption patterns than the typical District of Columbia worker in that they spend nearly all their income on consumption, we add an additional $50 million in Scenario 4 and Scenario 5 to account for this subpopulation's consumption behavior.
Source. Authors' calculations.

Scenario 1 represents only the workers earning $15 per hour or less in the base year of 2017 and assumes no offsetting economic responses from affected businesses. Scenario 2 includes spillover effects inclusive of workers earning $15 to $18 an hour in 2017 along with workers within Scenario 1. Scenario 3 adds the assumption of offsetting productivity gains to Scenario 2, accounting for increases in worker productivity and reduced recruiting and retention costs associated with higher wages, also referred to as an efficiency wage. Several economic studies have shown that higher wages reduce employee turnover and increase productivity, and these factors can significantly offset higher payroll costs for businesses (Boushey & Glynn, 2012; Cascio, 2006; Dube, Naidu, & Reich, 2007; Howes, 2005; Reich, Hall, & Jacobs, 2005). We estimate that these savings account for a roughly 30% reduction in business costs otherwise observed with the wage increase, factoring in the results of these studies.[7]

Scenario 4 adds the assumption of increased higher consumption levels by workers who earn higher wages because of the $15 MWP to Scenario 3. We employ a "representative consumer" in analyzing consumption and savings patterns. However, since the participants of our study are minimum wage workers, we make two additional assumptions to reflect the difference in their income tax paying and consumption patterns. Specifically, we assume minimum wage workers face much lower federal and state tax rates on additional wage income than a typical worker, and that they will spend nearly all their additional after-tax income on consumption.[8] This higher marginal propensity to consume for minimum wage workers is expected, in turn, to further increase demand by $50 million and at least partially mitigate citywide job losses (Fisher, Johnson, & Smeeding, 2014). Scenario 5 incorporates the assumptions of Scenario 4 but increases productivity gains from 30% to 75%, representing a stronger efficiency wage effect. The 75% assumption simulates a near zero effect on employment, consistent with Dube et al. (2010). Table 4 summarizes these five scenarios.

We consider Scenario 2 as a "worst-case" scenario, as it produces the largest job loss estimate and Scenario 5 as a "best-case" scenario because it produces the smallest job loss estimate. We consider Scenario 4 as the most likely case out of the five scenarios because it is feasible that the $15 MWP will (a) affect some workers earning more than $15 an hour; (b) spur at least some increased labor, capital, and operational productivity gains, as well as technological efficiency gains; and (c) boost consumption among a large share of the city's lowest earning workers.

Safety Net Interactions: Minimum Wages and the EITC

One purpose of the $15 MWP is to help the city's lowest wage-earning residents earn higher incomes to help mitigate the rapidly increasing cost of city living (Gould, Cooke, & Kimball, 2015). However, other social welfare programs exist, including but not limited to the EITC, Medicaid and the State Children's Health Insurance Program (CHIP), Temporary Assistance for Needy Families, Supplemental Nutrition Assistance Program

(SNAP), the Special Supplemental Nutrition Program for Women, Infants, and Children, federal and local Housing Choice Voucher Programs, and the Low-Income Home Energy Assistance Program.

While these programs are interrelated, this study focuses on examining the effects of the $15 MWP on EITC allotments likely to be dispersed to qualified recipients in 2021. The EITC program is examined for the following reasons: (a) the EITC and minimum wage are both work-based programs and may accordingly have understudied complementarities; (b) the District of Columbia refundable EITC, equal to 40% of the federal EITC, is the largest state or local supplement to the federal EITC in the country (Hardy, Smeeding, & Ziliak, 2018); and (c) the District of Columbia administrative data allow for a relatively novel analysis of city and federal EITC receipt amid MWP changes.

EITC Policy Micro Simulation Model

We complement the CGE analysis using the District of Columbia individual income tax and EITC policy micro simulation model (IEM). The IEM simulates the impact of the $15 MWP on citywide federal and local EITC receipts in 2021. The IEM is a comparative static model that estimates the incomes, federal and local EITC payments, and city income tax liabilities of directly affected working residents both with and without the $15 MWP. It is distinct from the CGE model, drawing on tax return data for each income tax filer in the District of Columbia. Whereas the CGE model forecasts employment levels, the IEM produces results in terms of income changes for resident workers filing city income tax returns. Ultimately, there will be 60,748 income-earning city residents directly affected by the $15 MWP in 2021.[9]

Affected Income Tax Filers. Over 350,000 District of Columbia residents filed "District of Columbia Individual Income Taxes." Individual income tax returns used in the policy simulation model were limited to 12-month residents with annual wage earnings between $3,000 and $32,000. Filers with earnings below $3,000 are dropped, under the assumption that their hours worked are low year-round and not due to low hourly wages. At the other end, the maximum annual wage income amount considered in this analysis is $32,000, which corresponds to annual earnings for full-time workers at $18 per hour. Among the roughly 93,000 tax filing records for District of Columbia residents that meet these criteria, we randomly selected 60,748 filers to represent working city residents between 2017 and 2021 who are likely affected by the $15 MWP, given that income tax data do not indicate filers' workplace or occupation. We then estimate the annual total wages for each worker-tax filer in this subpopulation for both the $11.50 MWP (baseline) and the $15 MWP (policy simulation) in years 2017 until year 2021.

Results

Employment

We produce five forecasts of annual employment affects from the minimum wage between 2017 and 2032. These forecasts ultimately represent varying levels of reduced future employment. In this setting, employment is equal to the current level of jobs plus the additional new jobs generated from the city's growing economy. As of June 2018, total jobs in the district grew at roughly 1.45% per year over 2014 to 2018, and annual average expected growth is approximately 0.7% between 2018 and 2022.[10] Figure 2 illustrates this for the most likely scenario only, showing that the city's economy and employment levels are predicted to grow with the $15 MWP.

In 2021, the Scenario 1 model forecast calls for 1,347 fewer employed residents, primarily in the retail, accommodation, and food industries, as a result of the $15 MWP—even as the city's economy and overall job market continues to grow (Figure 3). Under Scenario 2, the model forecasts 1,680 fewer employed residents, 1,160 fewer employed residents under Scenario 3, and 1,074 fewer forecast employed residents under Scenario 4. Finally, Scenario 5 incorporates an efficiency wage and forecast employment is lowered by 109 residents.

To put these forecasts into perspective as a share of the city's total forecasted resident employment, the worst-case scenario represents 0.43% of total resident employment, the most likely case (Scenario 4) represents 0.28% of total resident employment (or 1.8% of the city's low-wage resident employment base), and the best-case scenario represents 0.03% of total resident employment.

Interestingly, Table 5 shows that city residents are estimated to account for 60% to 65% of the job losses in the short term, but 5 years later in the long term account for 77% to 82% of the job losses. Many city residents that are displaced by disemployment from this policy are expected to eventually regain employment, including within the neighboring counties of Maryland and Virginia where the minimum wage is lower. The model accounts for worker displacement as one of a class of dynamic economic interactions that take place throughout the regional labor market over the study period. Thus, the $15 MWP could cause some low-wage city resident workers to be crowded out of the city's job market through increased labor market competition from bordering counties in Maryland and Virginia, given the wage differentials between nearby jurisdictions (Fahimullah et al., 2017).

Minimum wage partial equilibrium analyses oftentimes provide explicit employment elasticities generated from regression analysis, while the CGE model uses embedded regression-derived elasticity parameters. The CGE model produces annual employment impacts for the city's labor

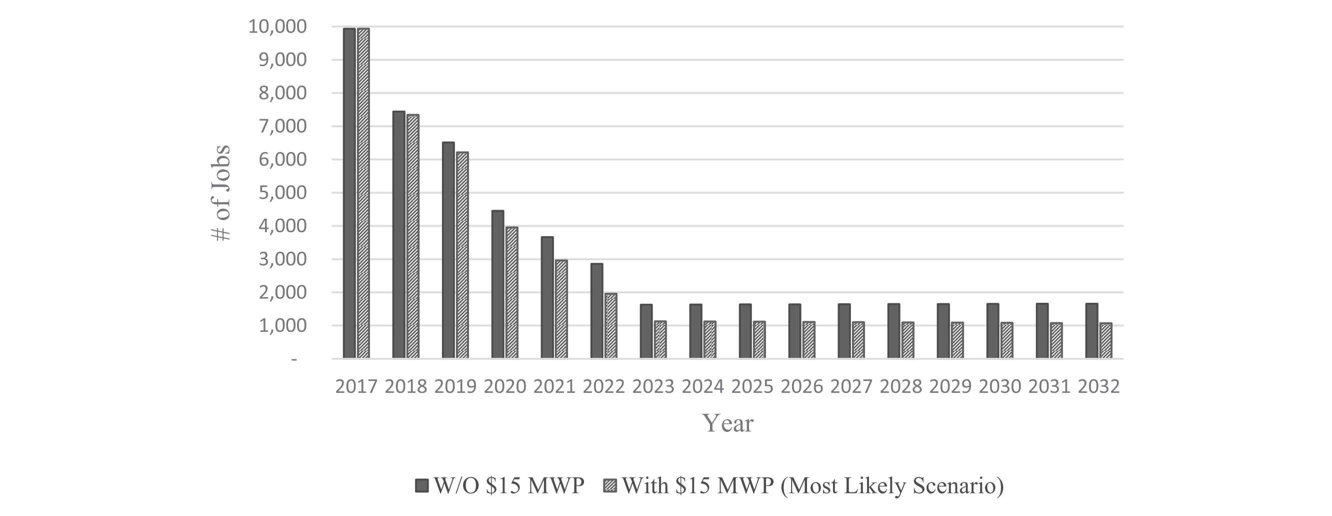

Figure 2. Estimated change in total jobs with and without District of Columbia $15 MWP in the District of Columbia economy: Most likely scenario.
Note. MWP = Minimum Wage Policy.

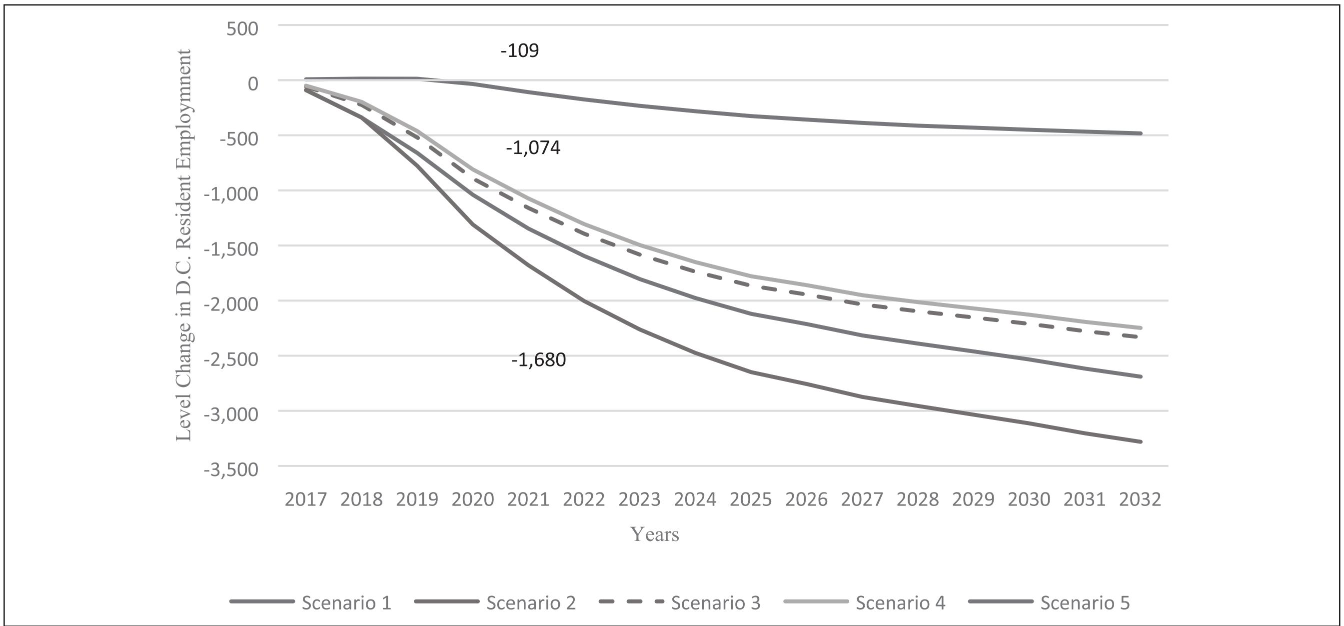

Figure 3. Change to baseline resident employment level, by scenario.

Table 5. Forecasted Employment Elasticities and Changes in Employment Levels From the District of Columbia (DC) $15 MWP.

		Employment changes					
Scenario	Elasticities (2021)	For DC residents (2021)	For all workers (2021)	DC share (2021)	For DC residents (2026)	For all workers (2026)	DC share (2026)
Worst case	−0.11	−1,680	−2,758	60.9%	−2,757	−3,597	76.6%
Most likely case	−0.09	−1,074	−1,652	65.0%	−1,860	−2,262	82.2%
Best case	0.00	−109	+18	—	−358	−173	—

Note. MWP = Minimum Wage Policy.
Source. Computable general equilibrium model-based calculations.

market, and from these estimated job losses total employment elasticities for the city's workforce can be calculated. Per the model, Scenario 2 yields an employment elasticity of −0.11, similar to Neumark, Sala, and Wascher (2014) and Sabia et al. (2012). Scenario 4 produces an employment elasticity of −0.09, similar to the minimum wage elasticities found by Belman and Wolfson (2014). Scenario 5 produces an employment elasticity of approximately zero, similar to Dube et al. (2010), Card and Krueger (2000), and Addison et al. (2009, 2012).[11] These findings suggest that one possible reason for the varied elasticity estimates in the minimum wage literature is that different jurisdictions may implement higher minimum wage policies under unique social, political, and economic environments. As described previously, yet another explanation for varied results hinges on model differences: the neoclassical model tends to predict job losses in all but the most extreme cases.

The employment effects depicted in Scenario 2 (worst case) and Scenario 5 (best case) illustrate the extreme range of possibilities. Over the 23 years between 1993 and 2016, the District of Columbia raised its minimum wage from $4.25 to $11.50. There is no empirical evidence that affected city businesses responded to higher minimum wages in ways that comport perfectly with either Scenarios 2 or 5, although an increasing share of modern minimum wage studies support an efficiency wage frame. We therefore consider Scenarios 1, 2, and 3 as less likely and assess Scenario 4 as an intermediate scenario that more likely reflects the economic conditions of the city. For the remainder of this study, we anchor our discussion onto forecasts based on Scenario 4 from 2017 to 2032.

Employment Sensitivity to Productivity Assumption

Scenario 4 assumes that increased business productivity offsets 30% of the increase in labor costs. To gauge the sensitivity of the estimated employment effects to the 30% productivity assumption, we re-ran the model with business productivity savings equal to 45% and 15% of the increase in costs. We found that these two auxiliary scenarios almost symmetrically bracketed the 30% scenario estimate for years 2017 to 2032. In year 2021, the 15% auxiliary scenario resulted in an estimated 2,313 job loss, which is 27.3% higher than the original estimate of 1,817 fewer total jobs for all city workers under the most likely scenario. The 45% auxiliary scenario resulted in an estimated 1,319 disemployment, which is 27.4% lower than the original estimate under the most likely scenario. The same symmetry holds for 2026. The sensitivity analysis indicates that a small decrease or increase in the productivity assumption produces a nontrivial but proportionate decrease or increase in estimated total jobs created in the city relative to the most likely scenario.[12] Therefore, while we estimate that 1,817 fewer jobs will be held by city workers under the most likely scenario, the importance of increased firm productivity among affected businesses looms large; our model consequently forecasts a range between 1,321 and 2,313 total fewer jobs.

Economy-Wide Impacts

From the initial economic shock of $528 million in increased business costs and $493 million in additional income likely to be received by city workers in 2021, the model also estimates how these shocks will be financed and absorbed. As shown in Figure 4, in 2021, $171 million or 32% (using $528 million) of the cost will be financed by higher consumer prices, $141 million (27%) will be financed by lower profit levels, and $118 million (22%) will be financed by business productivity gains (Figure 4). From the employee and business vantage point, both bars equal $528 million in absolute value. The positioning of the two bars in Figure 4 are different once negative values are incorporated for job loss, payroll tax, and lower wage growth from the employee perspective. This figure also highlights the interconnectedness between workers, consumers, and businesses.

Among low-wage city residents, we estimate that the vast majority of the approximately 61,000 directly affected workers will receive an additional $197 million in income. However, 1,074 resident workers will lose $46 million through job loss, despite overall job growth in the city, and nonminimum-wage employees in the affected industries in the city will forego $18 million in wage growth income as of 2021. These figures are calculated using the share of city residents estimated to experience job loss (1,074) relative to all city workers (1,652) estimated to experience job loss.

Affected city businesses absorbing higher labor costs are expected to raise consumer prices in response to higher business costs. This could render them less competitive than nearby firms in the bordering counties of Maryland and Virginia, subject to lower minimum wages, although there are likely tangible benefits to locating within the nation's capital. The model estimates that, on average, city-wide prices rise 0.2 percentage points above baseline inflation in 2021 for all goods and services sold in the city, with the highest increase occurring in the food service and restaurant sector, an expected average increase of almost 1.5 percentage points above the baseline in 2021. The model also predicts that higher prices will lower city business exports of goods and services by $126 million, primarily to Maryland and Virginia consumers (Table 6). This translates into a −0.94% decrease in city net exports, which, in turn, will cause gross state product to grow $61 billion (0.06%) less in 2021 than the baseline.

Assessing the Estimated Income Gains From the CGE

The IEM is a comparative static model that, unlike the CGE, does not incorporate behavioral changes. To understand whether the IEM is biased in favor of forecasting a significant

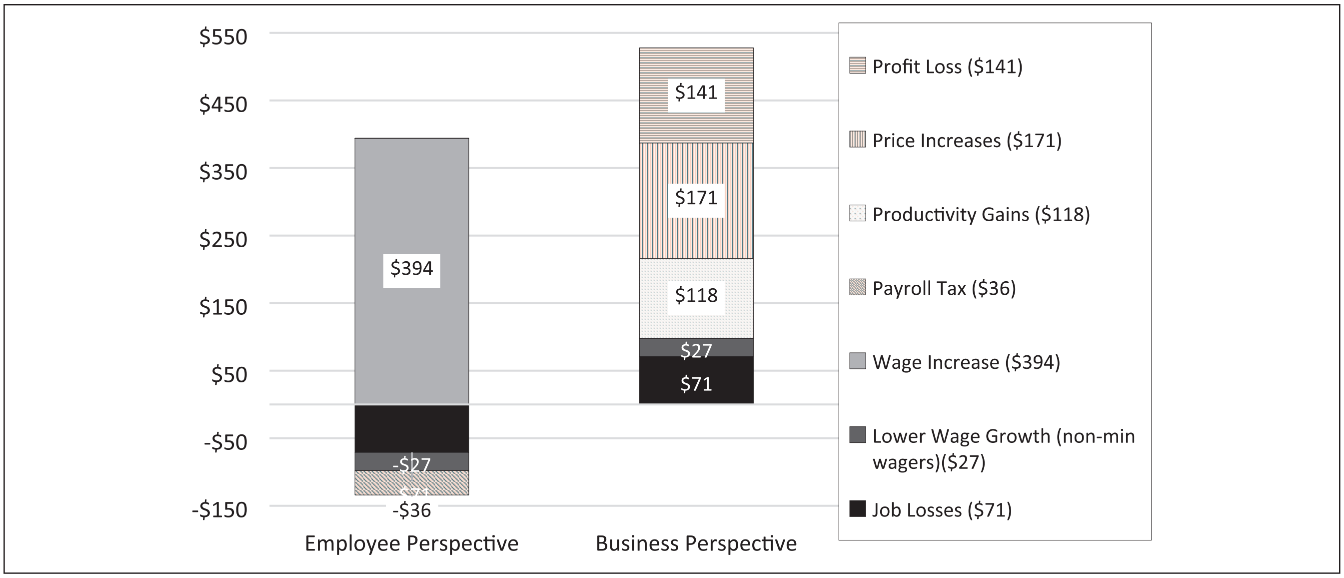

Figure 4. Financing the District of Columbia $15 Minimum Wage Policy, 2021 (millions $s).

Table 6. Forecasted Economy-Wide Effects of the District of Columbia $15 MWP (Billion $s).

	2021		2026	
	$ Amount change	% Change	$ Amount change	% Change
Consumption	$72	0.19	$49	0.12
Investment	−$3	0.02	−$24	−0.17
Government expenditures	−$10	−0.02	−$21	−0.04
Net exports	−$126	−0.94	−$144	−0.96
Net change in real GSP	−$61	−0.06	−$140	−0.11

Note. MWP = Minimum Wage Policy.
Source. Computable general equilibrium model-based calculations.

income gain, we again examine the statutory 39.4% increase in the city's minimum wage between years 2014 and 2016 ($8.25 to $11.50) using the District of Columbia's administrative income tax data for years 2011 to 2016.

We examine all 10,670 city tax filers that remained in the city, continued to earn wage income, and receive the EITC annually from 2011 to 2016, finding that these workers had incomes that increased an average of 3.0% per year from 2011 to 2013, the years immediately preceding the city's initial minimum wage increases (Figure 5). However, these workers experienced more than a doubling (6.4%) of their annual average income growth from 2014 to 2016, which corresponds to the increased minimum wage to $11.50. While this cannot be interpreted causally, it is consistent with the possibility that the city's minimum wage contributed positively and significantly to income growth. Among a series of locally focused minimum wage studies, one study estimated increased earnings of $3,000 or 18% higher (Reich et al., 2016) and another (Acs et al., 2014) estimated increased earnings in the range of $3,380 to $6,760. Using city tax data, we find that average earnings in 2016 are $2,807 higher than average earnings in 2013 for the District of Columbia EITC population from 2011 to 2016.

EITC Impacts

The IEM reveals that 63% of the city's EITC population will experience wage growth as a result of the $15 MWP.[13] In the aggregate, and as shown in Table 7, resident EITC recipients subject to the $15 MWP who remain employed in the city are estimated to lose $10.4 million in federal EITC and $6.0 million in District of Columbia EITC in 2021 while gaining $54.6 million in higher wages. The reduced total EITC payments primarily derive from higher annual wages, causing more EITC recipients to be either newly in, or further along, the "phaseout" portion of the EITC program, and by rendering some previously eligible EITC recipients ineligible. The model simulates that in 2021, 4,490 fewer District of Columbia residents will receive the EITC due to an estimated 803 EITC recipients who experience job loss, and 3,673

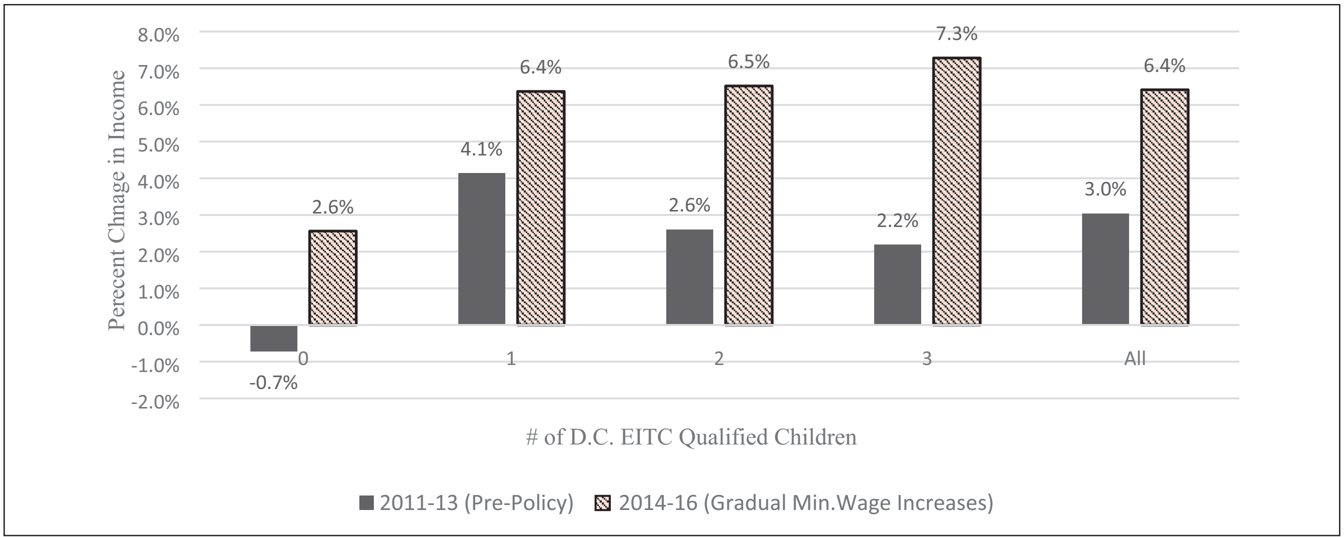

Figure 5. Average 2-year income growth rate for EITC recipients by number of children.
Note. EITC = earned income tax credit.

Table 7. Forecasted Total Net Impact of the District of Columbia (DC) $15 MWP on All DC EITC Recipients in 2021 (Million $s).

			Net difference	
	Without $15 MWP	With $15 MWP	$ Amount	% Change
Wage and salaries	$595.3	$649.9	$54.6	9.2
DC individual income tax	$10.0	$10.5	$0.5	5.0
Federal EITC	$92.2	$81.8	−$10.4	−11.3
DC EITC	$36.9	$30.9	−$6.0	−11.3

Note. MWP = Minimum Wage Policy; EITC = earned income tax credit.
Source. Calculations derived from IEM simulation.

childless workers who will earn more annual income than the federal EITC allows for this subgroup of filers. The share of recipients in the phaseout portion of the EITC program, where credit allotments begin to fall, is expected to go from 55% without the policy to 68% with the policy in 2021 (see Nichols & Rothstein, 2015 for a description of EITC design). For the $11.50 MWP, Acs et al. (2014) found a 53% reduction in District of Columbia EITC for part-time workers and no reduction for full-time workers. We find, per Table 7, that part-time workers receive 36% less District of Columbia EITC, while full-time workers receive 7% less District of Columbia EITC.

On average, resident low-wage workers affected by the $15 MWP will experience a 16.5% increase in earnings in 2021 (Table 8). We estimate that they collectively gain $192.2 million in higher wages and salaries, including $3,164 on average per person, but will lose $10.4 million in federal EITC and $6.0 million in District of Columbia EITC. This is similar to results using OES, BEA, and ACS data, which estimate a roughly $197 million earnings gain, as shown in Table 2. The overall interaction between the $15 MWP and the EITC produces a net gain on the order of $180 million. On a per-person basis, the estimated average earnings increase for an EITC recipient is $3,097 under the $15 MWP, leading to a predicted $331 reduction—$194 in federal EITC plus $137 in District of Columbia EITC—in the size of the EITC for a full-time resident worker employed in the city through 2021.

Conclusion

Using a CGE model, we estimate the economic impacts of the $15 minimum wage on the District of Columbia economy in 2021. We also use a comparative static microsimulation model to estimate the effect of higher wages from the $15 MWP on federal and local EITC levels and net-EITC income in 2021. We forecast that the increase in the District of Columbia's minimum wage rate will produce significant income gains for most of the city's lowest wage earners and job losses for a relatively small number of city residents compared with the city's employment base. The $15 MWP is predicted to disproportionally affect residents working in retail, health care, social assistance, accommodation, and

Table 8. Impacts of Forecasted District of Columbia (DC) $15 MWP Across the Workforce in 2021, All DC Residents (Million $s).

	Full-time workers		Part-time workers		Job losers	Total	
	$ Amount	% Change	$ Amount	% Change	$ Amount	$ Amount	% Change
Change in wage and salaries	$235.3	21.7	−$26.1	−32.3	-$16.9	$192.2	16.5
Change in total DC individual income tax	$4.3	16.4	−$0.3	−29.0	−$0.4	$3.6	13.5
Change in federal EITC	−$4.8	−7.4	−$4.6	−35.6	−$1.0	−$10.4	−11.3
Change in DC EITC	−$3.4	−7.4	−$1.8	−35.6	−$0.7	−$6.0	−11.3
Net impact	$231.3	19.0	−$32.8	19.0	−$19.0	$179.5	13.6
# Impacted tax filers	52,039		7,635		1,074	60,748	

Note. MWP = Minimum Wage Policy; EITC = earned income tax credit. In this analysis, we designated residents earning between $3,000 and $10,000 as part-time workers and residents earning more than $10,000 as full-time workers. In 2021, without the $15 MWP there were 12,192 part-time earners in the simulation, but with the significant income gains under the new policy there were only 7,635 part-time workers in the analysis.
Source. Calculations derived from IEM simulation.

food service industries, and the costs of the policy are absorbed by higher consumer prices, lowered firm profits, and higher business productivity.

The higher prices resulting from the $15 MWP lower the forecasted 2021 gross state product by 0.06%. On the other hand, there are substantial forecast net gains accruing to many resident workers; 63% of the 60,000 EITC recipients living in the city are predicted to lose a total of $16.4 million in federal and local EITC payments in 2021, while gaining $54.6 million in additional earnings by way of the $15 MWP. This suggests a net gain for the typical EITC recipient; in addition, the policy reduces some direct government costs associated with income support for the working poor. That said, other safety net program interactions are unaccounted for and costs associated with supporting displaced workers, if any, would ostensibly be absorbed by local governments throughout the national capital region—District of Columbia, Maryland, and Virginia.

This forecasting exercise, like all others we know of, has limitations. The underlying model assumes a perfectly competitive neoclassical labor market, imposing some level of predicted job loss. In so doing, it does not allow for monopsonistic labor markets—how contemporary labor economic research increasingly characterizes many local labor markets. We attempt to build in an efficiency wage framework using a range of job loss, but nonetheless we cannot fully account for these decisions. An assessment of these and similarly designed forecasting models should thus note that job loss estimates could be overstated. Related to this, the model cannot generally assess the distributional consequences of minimum wages beyond occupation-based earnings differentials. For example, these and similar models are generally not calibrated to assess the socioeconomic characteristics of labor market participants who potentially lose or retain employment.

In short, the model is an informative and at once imperfect tool—one that imposes assumptions increasingly viewed as restrictive. Economic policy recommendations should therefore acknowledge and account for these underlying model imperfections.

For the purposes of evaluating the benefits and costs of the minimum wage increase, in an "all else equal" calculation, the minimum wage represents redistribution from capital to labor. Accordingly, policy makers and elected officials are solving a complex political economy problem, assigning their own social welfare weights on owners of capital versus labor; in this context they are both "people." To do so, policy makers must consider the weight or importance to assign to producers versus consumers in what is ultimately their own social welfare function, influenced by a range of factors including political feedback from constituents, before assessing the benefits and costs with respect to comparing firm-level profit losses versus worker-level earnings gains.

This study is among the first to conduct an ex-ante general equilibrium analysis of a large local minimum wage increase to $15. The forecasted economic impacts may or may not be generalizable to other jurisdictions implementing such a broad-based $15 MWP. Notwithstanding the significant increase in annual income to the majority of affected workers, the results from our forecasting model suggest that the effectiveness of such a policy is likely to depend of the ability and willingness of a region's economy to (a) absorb higher prices; (b) reallocate those displaced by job loss—by way of some combination of social welfare policy and workforce interventions; (c) promote and increase business and labor efficiency; and (d) accept lower firm profits, even if only temporarily.

Appendix A

Descriptive Comparisons to Previous Citywide Minimum Wage Changes

To help assess and compare our model's conclusion of relatively modest disemployment between years 2016 and 2020—when a 30% increase to the MWP occurs—we tabulate employment changes following a statutory 39% increase in the city's minimum wage ($8.25 to $11.50) between 2014 and 2016. To do so, we examine employment in the city's food industry from 2014 to 2017 (1 year after full implementation) and compare it to the 2011 to 2014 period. Although REMI is a forecasting model that incorporates all current D.C. area macroeconomic data, it cannot run historical forecasts or control for historical variables. We are thus unable to control for the range of prior historical economic factors, thereby preventing us from using REMI to formally assess previous minimum wage increases over the 2014 to 2016 period. We instead observe employment shifts following this prior minimum wage change, noting that the magnitude of this 2014 to 2016 policy change was similar to that of the $15 MWP.

We find that, after the city minimum wage increased between 2014 and 2017, employment in the city's food industry decreased 6.1% relative to the 2011 to 2014 period. Simultaneously, employment in the region's food industry increased 0.82% over the two periods. We compared these employment levels to those in the city's business and financial occupations to assess a worker group less likely to be affected over the same two periods. Jobs in these select occupations, which account for a large share of private city employment and are sensitive to citywide economic conditions, increased 2.5%. To be clear, we cannot attribute the difference in employment changes to the minimum wage policy. On the other hand, we cannot rule out the possibility of some previous labor market disruption from minimum wage increases.

To summarize, the region's employment data indicate that jobs in the city's food industry decreased by 4.4% (2,379 actual jobs) from 2014 to 2017, after controlling for employment changes in the region's food industry and the city's business and financial occupations.[1] While the statutory 39% increase ($8.25 to $11.50) in the city's minimum wage between years 2014 and 2017 is correlated with a simultaneous decline in the employment level in the city's food industry, it is not possible to rule out other factors that are unobserved, including zoning and land use policy, local development initiatives, economic conditions, and technological change. Moreover, it is not possible to rule out mobility across other nonfood-related occupations within the low wage labor market.

Other Safety Net Program Interactions

An additional concern is that increased income from the $15 MWP may be so large as to disqualify low-wage residents for one or more important social welfare benefits. While beyond the scope of this study, it is nonetheless important to consider how minimum wages interact with the safety net, as well as whether and how the workforce and job training system can absorb workers if they are impacted by the policy change (Grogger 2003; Moffitt 2015). As program eligibility is concerned, many programs contain a range of provisions to enhance work incentives, including gradual phaseouts of near-cash program benefits, standard deductions for household size, earnings disregards, and allowances for heating, cooking, electricity, and other utilities (Steuerle, 2015).[2] Many part-time and full-time workers would still qualify for safety net benefits. For example, low income families in the city with incomes below $35,000 in 2018 for a family of four are eligible—though not entitled—to receive rental housing subsidies.[3] For food assistance (SNAP), a household of two must have a maximum salary of $20,000 or less to be eligible. If anything, minimum wage workers would likely combine higher earnings with SNAP and the EITC (Hardy et al., 2018a).

APPENDIX B: Selected REMI PI+ Equations and Parameters

REMI CGE Labor Demand Elasticities

Below, we provide a more detailed description of the REMI computable general equilibrium model, adapted from descriptions of the model provided by REMI (2017).

With an output in sector i and intermediate input determined, the optimal labor and capital demand in sector i can be calculated from a constant returns-to-scale Cobb-Douglas function of value added for sector i:

$$VA_i = A_i\left(L_i\right)^{\alpha_i}\left(K_i\right)^{\beta_i}\left(F_i\right)^{\gamma_i}, \tag{1}$$

where A_i is total factor productivity, L_i, K_i, and F_i are labor, capital and fuel sector i respectively, and $\alpha+\beta+\gamma=1$.

Demand for labor can be derived through cost minimization and be expressed as

$$L_i = VA_i\left(\frac{1}{A_i}\right)\left(\frac{w_i}{\alpha_i}\right)^{\alpha_i-1}\left(\frac{r_i}{\beta_i}\right)^{\beta_i-1}\left(\frac{f_i}{\gamma_i}\right)^{\gamma_i-1} \tag{2}$$

where w_i is the wage rate, r_i is the cost of capital, and f_i is the cost of fuel, the short run labor demand elasticity (assuming constant product price and fixed level of capital) is given by:

$$\sigma_L = \frac{\partial ln\left(L_i\right)}{\partial ln\left(w_i\right)} = -\frac{1}{1-\alpha_i} \tag{3}$$

However, beyond the very immediate short run, our assumption of constant product price and fixed level of capital will not hold. As the cost of production increases (thus less is produced), the demand for labor will fall. Also, when the wage for labor in industry *i* increases, demand for labor decreases as the price of capital is now relatively cheaper, and it pays to substitute capital for labor until the share of income going to labor, capital, and fuel are equal to α, β and γ, respectively. Our CGE model generates long-run elasticities that reflect the product demand elasticity and capital labor substitution.

The long-run elasticity is given by $n + (1 - \alpha_i) r$, where n is the product demand elasticity and r is capital labor substitution elasticity, which is 1 for Cobb-Douglas production function (Benewitz & Weintraub, 1964). Note that labor demand elasticities for each industry generated by our CGE model not only reflect labor wage relationship for each industry, but also reflect the wage increase in other industries. For example, rising wage in industry *i* will impact product price and product demand for industry *i*, and through input-output relationships may impact product demand for all other industries, and hence may impact labor demand by these industries. Table A1 shows the short-run labor demand elasticity assuming constant product price, fixed level of capital, and no change in capital, labor, and technological productivity for select industries in the District of Columbia. However, to allow for a new regional general equilibrium, the model allows for price adjustments, capital-labor substitutions, labor force migration, and technological changes. These binding dynamics produce a labor demand elasticity in 2021, vis-à-vis the respective employment and wage changes also in 2021.

Appendix Notes

1. We estimated that the net 4.4 percentage point decrease in the city's food occupation resulted in 2,379 fewer jobs in the 2014 to 2017 period compared to the 2011 to 2014 period. With a standard error of 1,287, the 95% confidence interval for the 2,379 fewer jobs estimate -4,953 and 195. Because we use jurisdictions close to the city as a control, the estimates may also be biased due to spillover effects on wages into these nearby localities.
2. https://www.fns.usda.gov/snap/fact-sheet-resources-income-and-benefits
3. U.S. Department of Housing and Urban Development, Program Income Limits, 2018. https://www.huduser.gov/portal/datasets/il.html

Table A1. Select Short-Run Labor Demand Elasticities and Employment Impacts.

Industry	Labor demand elasticity (short run)	Labor demand elasticity in 2021 (CGE)	Employment change in 2021(CGE)	Wage change in 2021(CGE)
22 - Utilities	-1.38	-0.80	-0.1%	0.1%
23 - Construction	-2.44	-1.64	-0.5%	0.3%
334 - Computer and electronic product manufacturing	-2.49	-0.17	0.0%	0.1%
42 - Wholesale trade	-2.01	-0.41	-0.1%	0.2%
44-45 - Retail trade	-2.33	-0.32	-1.1%	3.4%
492 - Couriers and messengers	-2.82	-0.26	-0.2%	0.8%
485 - Transit and ground passenger transportation	-1.94	-0.23	-0.7%	3.0%
487-488 - Scenic and sightseeing transportation and support activities	-2.94	-0.23	-0.2%	0.8%
524 - Insurance carriers and related activities	-2.02	-0.05	0.0%	0.1%
55 - Management of companies and enterprises	-6.02	-1.60	-0.1%	0.1%
561 - Administrative and support services	-3.83	-0.13	-0.1%	0.8%
562 - Waste management and remediation services	-2.16	-0.26	-0.1%	0.5%
61 - Educational services; private	-5.89	-0.09	0.0%	0.5%
621 - Ambulatory health care services	-4.30	-0.32	-0.2%	0.6%
622 - Hospitals; private	-8.51	-0.06	0.0%	0.4%
623 - Nursing and residential care facilities	-7.52	-0.24	-0.6%	2.7%
624 - Social assistance	-5.19	-0.19	-0.3%	1.5%
711 - Performing arts and spectator sports	-1.98	-0.16	-0.3%	1.6%
712 - Museums, historical sites, zoos, and parks	-4.58	-0.09	-0.1%	1.6%
713 - Amusement, gambling, and recreation	-2.52	-0.18	-0.7%	4.2%
721 - Accommodation	-2.02	-0.16	-0.3%	2.2%
722 - Food services and drinking places	-2.89	-0.22	-1.4%	6.4%
811 - Repair and maintenance	-2.98	-0.27	-0.5%	1.8%
812 - Personal and laundry services	-2.15	-0.19	-0.7%	3.6%
813 - Membership associations and organizations	-4.38	-0.26	-0.1%	0.5%

Table A2. Price and Income Elasticities in Consumption Equation (Equation 1-7).

Commodity	Elasticity type	Necessities	Luxuries
All commodities	Income elasticity	0.61	1.34
All commodities	Price elasticity	-0.66	-1.65

Notes: All parameters and elasticities for Tables A2 through A9 are based on proprietary information from REMI Inc. Equations for each of the following tables can be found in REMI (2017).

Table A3. Consumer Price Elasticity (α and β in commuter share equation, equation 1- 17).

Region	α	β
All regions	2.89	1.62

Table A4. λ in the moving average of gap between optimal and actual capital stock equation (equations 2-12 and 2 -13). Speed of adjustment by investment type:.

Region	λ Value:
All regions	0.5

Table A5. Parameters in the Economic Migration Equation (Equations 3-6 Through 3-9), β1: Responses to Changes in Relative Employment Opportunity; β2: Responses to Changes in Relative Wage Rate.

Region	Parameter	Default	Alternative
All regions	β1	0.455	0.28
All regions	β2	0.271	0.28

Table A6. α1 in the compensation, wage, and earnings rate equations (equations 4-13 through 4-18).

Panel 1: Responses to Changes in Employment Opportunity		
Equation	Default	Alternative
Compensation rate	0.0605	0.0645
Wage rate	0.0627	0.0819
Earnings rate	0.0894	0.0852
Panel 2: Responses to Changes in Occupational Demand		
Equation	Default	Alternative
Compensation rate	0.0378	0.0388
Wage rate	0.0303	0.0364
Earnings rate	0.0174	0.0146

Table A7. Elasticity of substitution α in the Labor Productivity Equation Depending on Occupational Labor Access for Selected Occupations (Equation 2-1).

Occupation	Elasticity of substitution
Counselors and social workers	14.57
Miscellaneous community and social service specialists	14.57
Legal support workers	14.57
Preschool, primary, secondary, and special education school teachers	14.57
Other teachers and instructors	14.57
Librarians, curators, and archivists	14.57
Other education, training, and library occupations	14.57
Nursing, psychiatric, and home health aides	14.57
Occupational therapy and physical therapist assistants and aides	14.57
Cooks and food preparation workers	16.49
Food and beverage serving workers	16.49
Other food preparation and serving related workers	16.49
Building cleaning and pest control workers	16.49
Grounds maintenance workers	16.49
Animal care and service workers	16.49
Entertainment attendants and related workers	16.49
Funeral service workers	16.49
Personal appearance workers	16.49
Baggage porters, bellhops, and concierges; tour and travel guides	16.49
Other personal care and service workers	16.49
Retail sales workers	13.75
Sales representatives, services	13.75
Sales representatives, wholesale and manufacturing	13.75
Other sales and related workers	13.75
Material recording, scheduling, dispatching, and distributing workers	13.75
Secretaries and administrative assistants	13.75
Food processing workers	11.27
Material moving workers	11.35

Table A8. Price Elasticity of Demand (α) in the Market Share, International Exports Market Share, and Domestic Demand Market Share Equations for Selected Industries (Equation 5-1 through 5-5).

Industry	Default price elasticity of demand	Alternative price elasticity of demand
Utilities	2.37	2.93
Construction	3.07	1.68
Computer and electronic product manufacturing	4.62	2.96
Wholesale trade	1.64	2.04

(continued)

Table A8. (continued)

Industry	Default price elasticity of demand	Alternative price elasticity of demand
Retail trade	3.33	3.61
Couriers and messengers	3.16	1.50
Transit and ground passenger transportation	2.79	3.16
Scenic and sightseeing transportation; Support activities for transportation	1.85	2.65
Insurance carriers and related activities	1.22	1.50
Management of companies and enterprises	2.92	2.98
Waste management and remediation services	1.82	2.35
Educational services; private	1.30	1.55
Ambulatory health care services	1.96	2.86
Hospitals; private	1.46	4.40
Nursing and residential care facilities	2.13	2.90
Social assistance	2.20	1.50
Performing arts, spectator sports, and related industries	2.53	1.50
Museums, historical sites, and similar institutions	1.75	2.64
Amusement, gambling, and recreation industries	1.65	2.02
Accommodation	2.85	4.32
Food services and drinking places	2.85	4.93
Repair and maintenance	2.52	3.87
Personal and laundry services	2.52	3.16

Table A9. β in the Market Share Equation, Distance Decay Parameter in a Gravity Model for Selected Industries (Equation 5-2).

Industry	β Value
Utilities	2.71
Construction	2.91
Computer and electronic product manufacturing	1.88
Wholesale trade	1.36
Retail trade	2.54
Couriers and messengers	1.34
Transit and ground passenger transportation	2.28
Scenic and sightseeing transportation; Support activities for transportation	1.91
Insurance carriers and related activities	1.09
Management of companies and enterprises	2.83
Waste management and remediation services	1.62
Educational services; private	1.03
Ambulatory health care services	1.97
Hospitals; private	1.11
Nursing and residential care facilities	1.23
Social assistance	2.11
Performing arts, spectator sports, and related industries	1.68
Museums, historical sites, and similar institutions	0.81
Amusement, gambling, and recreation industries	1.04
Accommodation	1.93
Food services and drinking places	1.93
Repair and maintenance	1.74
Personal and laundry services	1.74

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Notes

1. The current study extends Fahimullah, Geng, Hardy, Muhammad, and Wilkins (2017), which assesses the effect of the city's $15 MWP on the regional economy.
2. In the Appendix A, descriptive historical employment statistics are presented and compared across different minimum wage regimes within the District of Columbia.
3. Prominent CGE models have been used in research institutions including the U.S. International Trade Commission, the Congressional Budget Office, the Economic Research Service of the U.S. Department of Agriculture, the World Bank, and the Urban Institute. Some CGE models factored heavily in the debate about NAFTA, the Kyoto Protocol, and the Trans-Pacific Partnership (Burfisher, 2017). The Patient Protection and Affordable Care Act was also analyzed using a CGE model (Ciaschini, Pretaroli, Severini, & Socci, 2014).
4. See http://www.bls.gov/oes/oes_ques.htm#overview, for a full data description.
5. See http://www.remi.com/wp-content/uploads/2017/10/Model-Equations-v2_1.pdf, for a description of the REMI model, as well as Appendix B.
6. Cassing and Giarratani (1992) found that for the goodness of fit of the model, REMI produced an average mean absolute percentage error (MAPE) of 2.40%. Statistical tests were also conducted concerning the forecasting ability of the model. The authors found that REMI not only produced "very small forecast errors" but also forecast the actual sharp upturns and downturns of the study period.

7. A 30% cost saving is based on several studies on the link between higher wages, lower turnover, and higher productivity. Fairris (2005) studied the impact of 1997 Los Angeles living wage policies on worker turnover, finding that turnover reductions represent 16% of the cost of the wage increase for the average firm. Mas (2006) analyzed the case of New Jersey police officers who were granted a wage increase of 17%, finding they were 12% more productive in clearing cases than those who were refused the increase.
8. In our simulation using District of Columbia income tax data, we found that a minimum wage worker in District of Columbia would pay a combined 15% federal and state marginal tax rate on their additional income, while the combined marginal tax rate for a typical District of Columbia consumer is about 33%. The savings rate difference is about 5%.
9. The CGE model estimates that the $15 MWP will affect 66,968 jobs in the city held by residents. Using ACS data, we find this population of workers holds, on average, 1.10 jobs. This computes to 60,748 resident workers.
10. See https://cfo.dc.gov/sites/default/files/dc/sites/ocfo/publication, for a description of local growth forecasts.
11. Appendix B provides labor demand elasticity measures for select industries most affected by the $15 MWP.
12. To test whether the linearity of the CGE model, we simulated very large labor cost shocks in 2021 to the city economy in intervals of $1 billion and up to $12 billion. The model estimates that a $1 billion shock will ultimately cause 6,300 fewer new jobs to be created relative to the current job growth forecast. If the model was linear in all regards, the model would estimate 12,600 fewer new jobs to be created with a $2 billion shock, 25,300 fewer new jobs to be created with a $4 billion shock, 50,600 fewer new jobs to be created with a $8 billion shock, and 75,900 fewer new jobs to be created with a $12 billion shock. Instead, the model estimated 12,500 (99% of the proportional amount) fewer new jobs to be created with a $2 billion shock, 23,900 (95% of the proportional amount) fewer new jobs to be created with a $4 billion shock, 43,700 (86% of the proportional amount) fewer new jobs to be created with a $8 billion shock, and 60,500 (80% of the proportional amount) fewer new jobs to be created with a $12 billion shock. These findings indicate that, even if business labor costs in the city would hypothetically increase 12-fold, the corresponding lowered number of new jobs created would be much less than the 12-fold initial amount. This indicates a bound on the forecasted, lower number of jobs created, suggesting there are a number of essential jobs that the city economy needs to operate, and that the model is not strictly linear in all cases.
13. We adjust the EITC schedule for inflation, and the appropriate 2021 tax credit amount is estimated for eligible tax filers with respect to income, family size, and marital status.

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