Blocked Pipes: The Economic Consequence of Skilled Worker Shortages

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The thinning of the supply of skilled labor is having major negative implications on the economy. This research explores the "skilled labor gap" by examining the plumbing industry and quantifying the economic value lost through inefficiencies and labor premiums. The analysis utilizes state-level panel data for the years 2010 to 2018, employing both a linear OLS model of pooled data and a random effects regression model to determine the relationship between the number of plumbers and the price of plumbing services (proxied in plumber wages). Price effects are modeled across industries to determine the effects on the overall economy.

Keywords: labor market, skilled labor, employment, skills gap

INTRODUCTION

There is a shortage of skilled trades workers in the United States. Skilled trades workers embody extensive knowledge, yet their education comes largely in the form of on-the-job training, apprenticeships and/or trade schooling, rather than the standard educational pathway of high school diploma followed by a bachelor's degree from a four-year university. Skilled trades workers include plumbers, electricians, HVAC technicians, mechanics, etc. that make the economy function smoothly (and comfortably). Concerns regarding skilled labor shortages have been raised periodically over the last few decades. (Business Round Table: 1983) The conversation has been elevated in recent years as workers of the baby-boomer generation exit the workforce without significant replacement inflows from the younger generations. A "college-or-bust" mentality that has become prevalent in US secondary education has disincentivized alternate career pathways (i.e., trade schools and apprenticeships) while flooding universities with high school graduates.

Skilled worker shortages can lead to additional costs more broadly in the economy. Most obviously and directly, growing demand for skilled labor combined with a stagnant supply of such labor will lead to upward pressure on the price of skilled labor. The problem extends beyond higher wages for skilled workers (which is not necessarily a bad thing). With a limited supply of skilled tradespeople, there are increasing opportunities for inefficiencies in work, inconsistencies in quality, and shortages in availability which could significantly delay projects.

According to Albattah, et al (2015) and Stockard (2019), the increasing retirement of experienced workers is a leading cause of labor stagnation in the trades; under such a scenario, with supply unable to keep up with demand, increasingly expensive services may yield suboptimal results as newer, lesser-trained trades workers start to become the industry norm. (Weyers: 2019) This problem is largely societal and structural, resulting from the 4-year-university focus on channeling potential trades workers away from career opportunities that might suit their interests, pay well, and come with lower enrollment costs. A path dependency is formed: high school seniors opt for university degrees, whether because of familial pressure, social pressure, or simply familiarity. With a university education and degree in hand, it may seem unappealing or unfeasible to consider a job in the trades, even if there are favorable market conditions.

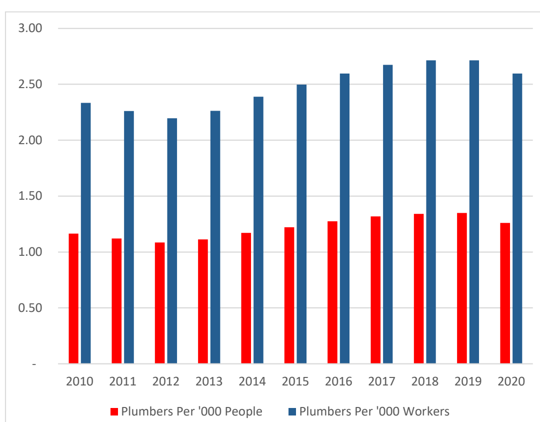
This research focuses on one particular skilled industry, the plumbing industry, to assess the economic costs associated with such a shortage of plumbers. Standard economic theory tells us that a shortage of something – be it goods, services, labor, or something else – puts upward pressure on the price commanded by that something. In the case of the plumbing industry the labor shortage means higher prices for plumbing services. Households will pay higher prices when employing plumbing contractors, but also plumbing contractors will pay higher wages to employees, as the pool of potential workers is limited. The analysis considers prevailing plumber wages as the proxy indicator for plumbing service prices. In addition to increased wages, there are likely to be economic losses resulting from inexperience, inefficiencies, the need for training, and the ongoing hiring process. In this research, we first estimate the current plumber employment gap and then the economic losses stemming from their absence.

The research is organized as follows: In section 2, we trace trends in plumber employment; in section 3, we review literature related to skilled worker shortages and trends in vocational education/training; section 4 introduces an econometric model quantifying the effect of the labor shortage on plumber wages and how these costs lead to dislocations in the overall economy; sections 5 and 6 discuss the results of the regressions and their implications for the economy more broadly; and section 7 concludes.

Trends in the Plumbing Industry

According to BLS's Occupational Employment and Wage Statistics, as of May 2021 there were 417,620 plumbers, steamfitters, and pipefitters in the United States.[1] While the vast majority (upwards of 82.9 percent) work in the construction industry, plumbers can be found in nearly every sector of the economy. The number of plumbers has grown in recent years, both as a percentage of the population and as a percentage of the overall labor force; however, the rate of plumber employment growth tapered off in the mid-2010s. Figure 1 summarizes the trends in plumber employment over the 2010s.

FIGURE 1
PLUMBER EMPLOYMENT



This drop off is more pronounced when examining the number of plumbers per million dollars in construction spending. This provides a glimpse into the underlying dynamics of the skilled trades worker shortage – the supply of plumbers is simply not keeping up with demand for their services. Figure 2 on the following page highlights that, considering the ratio in either nominal or inflation adjusted terms, the number of plumbers working in America has not kept pace with construction demand.

The supply of skilled workers in the trades may also be in part explained by the limited demographic appeal of such roles (Alessandrini et al, 2014). According to BLS data, while women comprise 47.0 percent of the overall U.S. workforce, they comprise only 3.9 percent of construction occupations and 2.1 percent of plumbers. Most other skilled trades register female employment in the single digits.

FIGURE 2
PLUMBERS PER $ MILLION IN CONSTRUCTION SPENDING

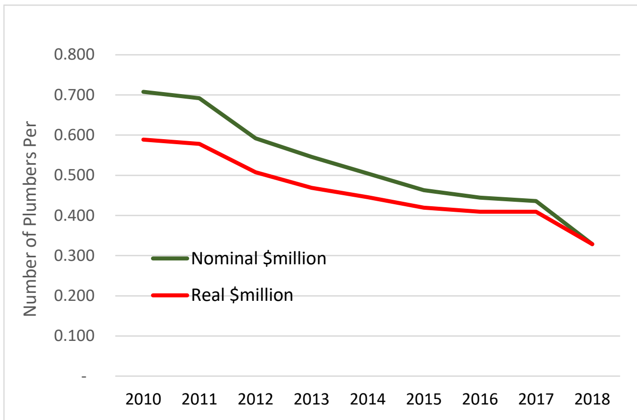


Table 1 on the following page outlines female employment in broad categories and a sample of some of the detailed construction-related skilled trade occupations. The table shows the 152.58 million people employed in the U.S. are divided into five broad categories: Management, professional, and related occupations; service occupations; sales and office occupations; production, transportation, and material moving occupations; and natural resources, construction, and maintenance operations. The latter category is then broken out into three sub-categories: Farming, fishing, and forestry; installation, maintenance, and repair occupations; and construction and extraction occupations. Finally, only a handful of construction and extraction occupations are displayed, which are meant to represent some of the critical skilled trades at the heart of our research. Female employment is greater than 50.0 percent in three of the largest broad categories: management, service, and sales occupations. Female participation in production, transportation, and material moving occupations is much smaller – roughly a quarter of the work force.

Finally, the female participation rate in the broad category of natural resources, construction, and maintenance is distinctively small. Moreover, farming and related occupations maintain about one-fourth female ratios when diving deeper into that category. Specifically, construction and extraction occupations (as well as installation, maintenance, and repair occupations) exhibit a paucity of female participation.

REVIEW OF LITERATURE

This research adds to the literature on the skilled labor shortage by quantifying the wage premium realized in the market due to an insufficient supply of skilled trades workers (in this case, plumbers) entering the workforce.

The skilled worker shortage is widely reported in contractor and homebuilding industry analyses. In a recent industry report put out by the National Association of Home Builders, fifty-five percent of responding single-family home builders indicated some level of shortage of plumbers. Fifteen percent of respondents considered it a “serious shortage,” while 40 percent indicated there was “some shortage.” Other skilled trades, such as home framing, carpentry, bricklaying, and masonry, reflect similar trends in worker shortages.

TABLE 1
FEMALE EMPLOYMENT BY OCCUPATION (2021)

Occupation	Total Employed (000)	Women (pct of total employed)
Total, 16 years and over	152,581	47.0
Management, professional, and related occupations	64,744	52.0
Service occupations	24,403	57.7
Sales and office occupations	30,166	61.5
Production, transportation, and material moving occupations	19,309	24.3
Natural resources, construction, and maintenance occupations	13,959	5.6
Farming, fishing, and forestry occupations	1,061	24.2
Installation, maintenance, and repair occupations	4,840	4.3
Construction and extraction occupations	8,057	3.9
Brick masons, block masons, and stonemasons	97	2.2
Construction equipment operators	360	3.0
Electricians	845	1.7
Plumbers, pipefitters, and steamfitters	587	2.1
Roofers	221	2.9

The Bureau of Labor Statistics (BLS) indicates that "Plumbers, pipefitters, and steamfitters" are expected to exhibit lower than average employment growth for the period 2021-2031 (an estimated 2% annually), even though there are a projected 48,600 openings for such jobs each year for the same period.[2] As workers either leave the field for other careers or retire, they leave behind an employment gap not likely to be adequately filled given current employment projections. This means that as the decade rolls along, the gap between the actual number of plumbers and the potential market for plumbers will widen. Stockard (2019) reflects on a related statistic – of an estimated 3.5 million vocational jobs expected to be created in the 2020s, about 2 million are expected to remain unfilled. Stockard cites retirement, economic expansion, and factors related to limited STEM and technical education for the decline. Albattah (2015) cites two reasons for long-term skilled trades worker shortages: lack of training and inability to attract new talent; short-term causes, he argues, include increasing demand in the workforce and retirement of the baby boom generation. Vocational training, which had once been a common component of secondary education in the United States, has been on the decline in recent decades.

In an article for The Atlantic, Meg St-Esprit (2019), explores the modern perception of trade schools as "second choice, second class" institutions. After generations of increasing importance leveled on attaining a bachelor's degree, a stigma has fallen on the pursuit of the trades. This "bachelors-or-bust" mentality, and the infrastructure built around it, is likely one of the contributors to the skilled worker shortages. Cappelli (2015) cites the drop off in high school vocational course offerings as a likely contributor to the shortfall in supply of skilled workers. Young students may opt for the four-year-degree pathway, forgoing trade school or apprenticeship opportunities. Universities indeed offer more than simply career prospects, but it may also be true that young students associate higher earnings potential with the four-year degree.[3]

Relatedly, the transition towards a "throwaway society" (McCullough, et al., 2018) in which consumer goods are bought and replaced rather than bought and repaired may have dampened incentives to consider trades employment. While the demand for plumbers remains high, the decline in repair-related jobs may have contributed to a general movement away from trade education. Further, the perceived volatility or uncertainty in trade industries may lead young adults to eschew a career in the trades as more and more things are simply thrown out and replaced.

While evidence of a skilled labor shortage abounds, there is little reported on the impacts of such a shortage. Albattah (2015) indicate that the shortage of skilled craft workers in the United States and Canada may already be leading to a "significant impact on project performance." A Conger.com article (2022) cites lower morale, higher wages, lower hiring standards, higher training costs, lower revenues, and more expensive products as some of the effects of the skilled labor shortage. The link between skilled labor shortages and higher prices for such services follows elementary economic intuition. However, the effects on standards and quality are a little less apparent. With fewer businesses or contractors, there is less opportunity to substitute away from inefficient or lower quality work, especially in the fields of new construction and home maintenance, where installing or fixing a broken piece of infrastructure is highly time sensitive.

Similar research exists in estimating labor market shortages. Sutcher, et al (2019) estimate the effects of the shortage of teachers. The authors consider a theoretical supply and demand framework, defining a shortage as an "inadequate quantity of qualified individuals willing to offer their services under prevailing wage conditions." A distinction emerges, however, when considering the cause of the shortage: Whereas the shortage of teachers may be a byproduct of inadequate or low compensation, we consider the skilled trade-worker shortage as perhaps a byproduct of social stigma and the path dependence of the diploma-to-bachelors route. These structural issues may require structural solutions, such as increased information and familiarity with trades-related skills.

THE PLUMBING INDUSTRY

Plumbing services encompass a broad range of activities, including unclogging blockages to installing large-scale systems across entire facilities or developments. In general, however, plumbing services can be broken down into two categories, installation, and maintenance.

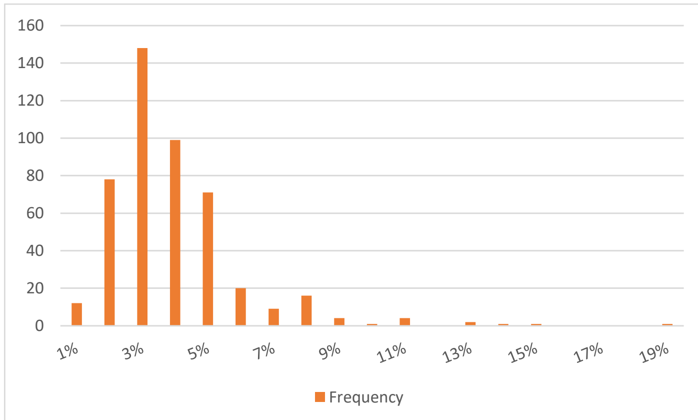
Demand for each of these types of plumbing services depends on a variety of factors. Installation of new systems occurs when an area's economy is expanding and new housing units, apartments, stores, and factories are being built. This is the category where surveys have identified widespread shortages in plumbing professionals. However, while it is important to have trained and skilled plumbers available to help build new facilities, it is just as important that these systems be properly maintained so that they can continue to operate for years. Therefore, it is essential that plumbers also be available on call to address problems as they arise. In other words, to perform maintenance.

This analysis examines both the construction and maintenance sectors of the plumbing industry and calculates different supply and demand models for both. As the analysis will show, while plumbers may be somewhat fungible across the two sectors, construction tends to take priority over maintenance when it comes to attracting skilled labor like plumbers. This section of the analysis will focus on the demand side of the equation.

Construction

Plumbing construction spending on new buildings, private and public, has consistently increased over the prior decade. In the four years from 2010 to 2014, plumbing spending rose almost 42.0 percent, from $88.33 billion to $125.39 billion. By 2018, spending had gone up another 48.5 percent to $186.23 billion. This is based on total spending divided by the number of plumbers times their output/employee. This means that about 95 percent of the construction spending on plumbing is not due to labor.

FIGURE 3
PERCENT OF NEW CONSTRUCTION SPENDING ON PLUMBING LABOR



Overall, new construction accounted for over 90 percent of all plumbing spending. This makes sense as new construction includes the cost of plumbers and plumbing equipment like pipes, toilets, faucets, and sinks. While these expenses are the main reason so much plumbing spending goes toward new construction, labor costs are also an important part of the equation. In fact, it is estimated that the cost of plumbers themselves generally represents between 2 and 5 percent of the overall cost of plumbing as it relates to new construction, depending on the state and year (Figure 3).

Maintenance

Spending on plumbing maintenance by businesses and households has varied between 2010 and 2018. In 2010, the nation spent over $6.69 billion in maintenance, which rose sharply to $10.53 billion in 2014, a 57.5 percent increase. Over the next four years however, maintenance spending dropped back down by 46.4 percent, to just $5.65 billion in 2018.[4]

Total

The US spending on plumbing services and supplies during the study period increased yearly since 2010. From 2010 to 2014, total spending on plumbing grew from $95.02 billion to $135.92 billion, a 43.0 percent increase. Spending then grew another 41 percent from 2014 to 2018, ending at $191.89 billion dollars. As was mentioned above, the bulk of this is due to the amount of new construction undertaken during that period.

ECONOMETRIC MODEL

This analysis contains two models that are used to estimate the impact of a plumber shortage on the overall economy. The first model examines the implications of a shortage of trained plumbers on plumbing wages. In this case, it is expected that the dislocation between the availability of plumbers and the demand for plumbing services will lead to higher wages. The effect on prices would be larger as plumbing contractors, plumbing maintenance providers (for example drain clearing and home repair services) and even plumbing instruction services would experience economic rents.

Once the effect of the shortage on wages is determined, the effect of these higher costs on industries that utilize contracted plumbers and plumbing services will be determined. These effects will be estimated using the IMPLAN input-output model of the US Economy.[5] According to IMPLAN, 519 of the 544 industry sectors in the United States utilize some level of plumbing services as a part of their production processes.

Data

Data from various publicly available sources is utilized to analyze the effect of the number of plumbers on plumber wage rates. Unless otherwise noted, data is collected at the state level, for the period 2010-2018. Unless otherwise noted, all value-based data is given in U.S. dollars (USD) using current (or nominal) prices.

Estimates of plumber employee counts and annual average plumber wages come from the Bureau of Labor Statistics' *Occupational Employment and Wage Statistics (OEWS)* dataset. The data reflects estimates for occupation code 47-2152 (Plumbers, Pipefitters, and Steamfitters) corresponding to the total employee (tot_emp) and mean annual wage (a_mean) variables. As estimated in OEWS, these numbers exclude any self-employed contractors. One benefit of the OEWS data is that it includes estimates based on occupational classification across various industries. For instance, in the case of plumbers, data reflect employees working in construction, utility, government, commercial, and so on. Moreover, the data isolates the plumber jobs themselves, rather than including salespersons or administrative employees working within plumbing companies. One potential extension of the model might be to incorporate BLS's *Quarterly Census of Employment and Wages (QCEW)* in place of OEWS data. QCEW groups data into the industry classification rather than the occupation classification; this would, in theory, capture the regression's impacts on the plumbing industry (all roles) and would not capture the impact on plumbers in non-plumbing NAICS categories.

Population data is derived from the U.S. Census Bureau's *Annual Estimates of the Resident Population for the United States, Regions, and Puerto Rico.* Resident population is one of the broadest categories of population used by the Census Bureau. It includes all residents, both civilian and armed forces, living within the United States; it includes both institutionalized and non-institutionalized persons in its count, and it does not exclude any age cohort. It is reasonable to assume that the overall market for plumbing will be determined, in part, by the overall number of people using U.S. plumbing infrastructure. In addition to the annual state residential population data (level), the model also includes the annual population change (first difference).

Labor force estimates and state unemployment estimates come from the BLS dataset *Local Area Unemployment Statistics*. The civilian labor force includes any working-age person who is either (a) employed or (b) actively seeking employment. This statistic is exclusive of military servicemembers. Including the civilian labor force and the state unemployment rates in the regression is meant to serve as a point of contrast for movements in plumber-specific employment.

Median household income data comes from U.S. Census Bureau's *Current Population Survey, Annual Social and Economic Supplements.* The choice of median income, rather than mean income, better reflects the economic well-being of the "typical" state resident. As such, it is not sensitive to the ups and downs of individuals at either of the income extremes. In particular, the wages of high-income earners may drastically alter an average income measure.

Construction spending estimates are derived from U.S. Census Bureau data. An annual national estimate of "total private construction" spending comes from the *Annual Value of Private Construction Put in Place.* This national number is broken into state-level approximations using the *Annual Value of Private Nonresidential Construction Put in Place by State* data. It should be noted that these two metrics are not identical; however, since total private construction data is not available at the state level, we feel that total nonresidential construction data serves as an adequate means of approximation.

We include a dummy variable to represent general political leadership by state by year. This dummy takes on the value of 1 when a state has a Democrat governor and 0 when the governor is Republican or Independent. In general, we assume Republican leadership to correlate to lower regulations and more business-friendly environments, while we expect Democrat-led states to favor interventionist policies such as minimum wages, unionization, etc. Additionally, Democrat-led states may have more bureaucratic red tape involved in establishing and running a business, which might limit the supply of skilled trades-workers. We believe Democrat-led states would likely correlate with higher plumber wages.

Gross state product, a measure for state-level economic output, is taken from BEA's *Regional Data: GDP and Personal Income* database. The "Gross Domestic Product (GDP) summary (SQGDP1)" report tracks real state output, given in 2012 dollars.

Inflation data comes from BLS's Consumer Price Index for All Urban Consumers (CPI-U). Since CPI is reported as an index number, we calculate the rate of inflation using the growth rate of CPI from one period to the next, such that $inflation_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}}$.

Finally, an estimate of the overall number of contractors is included. This data comes from the Bureau of Labor Statistics' *Quarterly Census of Employment and Wages* covering 2010 to 2018. Contractors fall under a few different NAICS codes, so for this analysis, "contractors" includes all those employed in NAICS sectors 236115 (New Single-Family Housing Construction), 236116 (New Multifamily Housing Construction), and 236118 (Residential Remodelers). For this study, we are interested in the movements of plumbers, specifically as a skilled labor class. For this reason, we believe the inclusion of an overall contractor count controls for general movements in the construction and maintenance industries, against which the plumber data will be contrasted.

Cost Model Specification

The dataset used in this analysis covers 50 U.S. states, plus Washington, D.C. (hereafter referenced as "51 states"), over the nine-year time period 2010-2018.

Pooled Ordinary Least Squares Model

We specify first a pooled ordinary least squares (pooled-OLS) model. A pooled-OLS model is specified by combining all data into a single regression of NxT observations. The model therefore assumes the same constant and slope coefficients apply for all states; further error terms are assumed to be independent and identically distributed. Second, we consider a fixed effect model, utilizing the random effects estimator. A fixed effect model will account for time invariant characteristic factors inherent to individual states. We find similar relationships for key variables in either case; however, the fixed effects estimated model offers a higher level of significance for the relationship between wages and number of plumbers.

We regress plumber wages on (1) the number of plumbers, (2) resident population, (3) year, (4) growth rate of resident population, (5) median household income, (6) the civilian labor force, (7) state unemployment rate, (8) the private construction spending estimate, (9) the governance dummy, (10) the percentage change in gross state product, (11) the change in inflation rate, and (12) the number of general contractors.

An ordinary least squares (OLS) regression is utilized in analyzing the pooled data. The year variable should control for any time-dependent or trend-related influences. However, pooled-OLS analysis might contain some bias since each state likely has certain time-invariant characteristics that may weigh on the model or the error terms. To control for time-invariant state characteristics, we ran a second model utilizing panel analysis, specified with a random effects estimator. The pooled-OLS model is specified.

$$PlumberWage_{i,t} = \beta_0 + \beta_1 PlumberNumber_{i,t} + \beta_2 Pop_{i,t} + \beta_3 gPop_{i,t} + \beta_4 Year_t + \beta_5 MedIncome_{i,t} + \beta_6 LaborForce_{i,t} + \beta_7 Unemployment_{i,t} + \beta_8 ConstructionSpending_{i,t} + \beta_9 Gov_{i,t} + \beta_{10} dGDP_{i,t} + \beta_{11} inflation_{i,t} + \beta_{12} NumberContractors_{i,t} \quad (1)$$

Panel Data – Random Effects Estimator

The random effects model omits a number of the variables used in the pooled OLS analysis due to insignificance: population, labor force, construction spending, state GDP growth, and inflation. The benefit of the random effects model is that it accounts for cross sectional heterogeneity that is not otherwise identified in the explanatory variables.

A basic form of the model is given by the equation:

$$Y_{i,j} = \mu + \beta X + U_i + W_{i,j} + \epsilon_{i,j} \quad (2)$$

where, in the model, $Y_{i,j}$ represents the prevailing wage of plumbers in state i at time j, μ represents the model intercept, U_i represents the state-specific unobserved factors, $W_{i,j}$ gives the state-specific random effect, and $\epsilon_{i,j}$ gives the error term. The term βX represents the observed explanatory variables and their coefficients.

A specific form formulation for our model would then be given by the following equation:

$$PlumberWage_{i,t} = \mu + \beta_1 PlumberNumber_{i,t} + \beta_2 gPop_{i,t} + \beta_3 Year_t + \beta_4 MedIncome_{i,t} + \beta_5 Unemployment_{i,t} + \beta_6 Gov_{i,t} + \beta_7 NumberContractors_{i,t} + U_i + W_{i,j} + \epsilon_{i,j} \quad (3)$$

The detailed regression results are reported in Table 2 below.

TABLE 2
REGRESSION RESULTS FOR PLUMBER WAGES, 2010-2018

	(1)	(2)
Constant	-2579318***	-1606940
	(-5.37)	(-3.88)
Number of Plumbers	-0.2352451	-0.2994816*
	(-0.92)	(-1.66)
Population	-0.123645***	
	(-7.35)	
Population Growth	-166748***	-131469**
	(-2.59)	(-2.21)
Year	1291.037***	817.0151***
	(5.41)	(3.98)
Med HH Income	0.3588253***	0.2091977***
	(6.51)	(3.71)
Labor Force	0.0243858***	
	(7.00)	
Unemployment	1963.191***	561.6766**
	(7.09)	(2.26)
Construction Spending	0.00000014***	
	(2.97)	
Gov Dummy	2605.299***	464.5909
	(3.39)	(0.78)
State GDP Growth	20502.44	
	(1.17)	
Inflation	-54483.63	
	(-1.38)	
Number of Contractors	0.213999**	0.1902924*
	(2.52)	(1.95)
Adj. R-squared	0.4956	0.3247
No. Observations	459	459

*,**, *** indicate significance at the 90%, 95%, and 99% level, respectively

Impact Model Specification

Based on the random effects analysis, for every additional 1,000 plumbers working in a state, the average wage of a plumber declines by about $300 annually in nominal terms. While this is statistically significant, it is a small amount. Other factors including the change in a given state's population, the governor's political party, and just the secular trend in wages have larger nominal impacts.

This model shows that plumbers, like almost anything else in the marketplace, are subject to the normal laws of supply and demand. However, even though the number of plumbers helps keep costs in check, what is most important is how the number of plumbers impacts the overall cost of plumbing services. This is calculated using two additional OLS regression models, one for new construction plumbing and the other for maintenance plumbing services. Since data on these costs are only available for even numbered years, models need to be constructed using only those data.

Construction

Starting with the largest segment of the market, construction, a new OLS model was constructed using data from 2010, 2012, 2014, 2016 and 2018. Initially, a model similar to the one developed to examine wages was constructed, with spending on plumbing for new construction added as the dependent variable, and wages shifted to an explanatory variable. This model also showed an inverse relationship between the number of plumbers and plumbing spending when controlling for other factors.

Overall, this model showed that spending on plumbing for new construction went down as the number of plumbers went up. Of course, econometric models of this type only show correlation and not causation, meaning that the model does not directly show that spending falls because of a change in the number of plumbers. However, other factors in the model suggest that this may indeed be the case. The amount spent on plumbing is negatively correlated with the number of plumbers, while at the same time, it is positively correlated with plumber wages rates, as well as with overall construction spending. It is also positively correlated with the cost of construction materials. This means that spending on plumbing rises along with overall construction spending, prices, and plumbing wages, while at the same time falling in response to a larger number of plumbers being available in the market. Based on standard economic principles, a relatively larger number of plumbers would lead to lower personnel costs, meaning that the availability of plumbers should lead to lower plumbing costs overall.

The average amount spent per state and year on plumbing services for construction across all six years and 51 states (including DC) was nearly $2.6 billion. The addition of 1,000 additional plumbers to a state would lead to a reduction in that state's costs of $68.6 million, or about 2.7 percent. Even though this is just under one-half of one percent of overall construction spending, the effects on the overall economy are large. Table 3 (1) on the following page outlines the coefficients for each variable. All data are at the state level.

As Table 3 (1) shows, construction plumbing expenses are negatively correlated with not only the number of plumbers working in a state, but also the state unemployment rate, the median family income, and the political party controlling the governor's mansion.

Construction plumbing expenses are directly correlated with the size of the labor force, overall construction spending, the number of general contractors in the state,[6] an index of the cost of various construction materials,[7] and the median wage rate of plumbers in the state (which is in turn related to the overall number of plumbers). In addition, there is a secular upward trend in construction expenses related to plumbing.

TABLE 3
EFFECT OF NUMBER OF PLUMBERS ON PLUMBER SPENDING FOR NEW CONSTRUCTION AND MAINTENANCE

	(1)	(2)
Constant	(70,959,617,506.39) (1.69)	34,251,339,116.78 5.88
Number of Plumbers	(68,629.83)** (2.72)	(8,806.15)*** (3.99)
Year	35,646,544.23 1.71	(17,023,767.96)*** (5.89)
Median Income	(24,955.28)*** (5.01)	
Population		76.33*** 3.72
Labor Force	118.04* 2.08	(88.17)* (2.12)
Unemployment	(93,964,095.66)*** (3.38)	(14,213,297.72)*** (3.82)
Construction Spending	0.15*** 31.29	
Government Dummy	(66,082,224.89) (0.86)	2,110,767.60 0.21
Number of Contractors	32,181.41*** 4.08	2,109.87* 2.03
Construction Materials Cost	50,359,000,230.50*** 3.53	(8,512,795,939.18)*** (4.50)
Plumber Wage	19,883.15*** 4.29	2,590.77*** 4.10
Adj. R-squared	97.2%	89.1%
No. Observations	255	255

*,**, *** indicate significance at the 90%, 95%, and 99% level, respectively

Maintenance

A similar model was developed for plumbing maintenance spending, again using data from 2010, 2012, 2014, 2016 and 2018. This model substituted spending on plumbing maintenance as the dependent variable. Interestingly, maintenance plumbing does not appear to be related to the amount of construction in an economy. As with the construction model, the inverse relationship between the number of plumbers and plumbing spending when controlling for other factors was statistically significant.

Overall, this model showed that spending on plumbing maintenance went down as the number of plumbers went up. As we have noted before, econometric models of this type only show correlation and not causation, meaning that the model does not directly show that spending falls because of a change in the number of plumbers. However, other factors in the model suggest that this may indeed be the case. For example, while the amount spent on plumbing is negatively correlated with the number of plumbers, it is positively correlated with plumber wages rates, while at the same time falling in response to a larger number of plumbers being available in the market. In addition, the amount of money spent on maintenance plumbing is correlated with population suggesting that this factor is driving spending rather than the number of plumbers creating new spending.

The average amount spent on maintenance plumbing services for construction across all six years and 51 states (including DC) was nearly $155.9 million per state per year. Adding 1,000 additional plumbers to a given state would lead to a reduction in costs of $8.8 million or about 5.6 percent. Table 2 outlines the coefficients for each of the variables.

As Table 3 (2) shows, maintenance plumbing expenses are negatively correlated with not only the number of plumbers working in a state, but as was the case for construction expenses, to a state's unemployment. Plumbing maintenance expenses are also negatively correlated with the labor force's overall size and construction materials' cost. As with plumbing expenses for new construction, those for maintenance are directly correlated with the number of general contractors in the state. Unlike the case with construction plumbing, these costs are also directly related to the current governor's overall population and political party. Opposite of the construction model, there is a secular downward trend in maintenance expenses related to plumbing.

Total

Overall, the number of plumbers matters after controlling for state factors and economic variables. As with any economic activity, plumbing is subject to supply and demand. Therefore, as the demand for plumbers increases, their wages rise. In addition, overall plumbing costs are impacted not only by plumber wages but other aspects of the plumbing supply chain, including contractor costs, materials costs, and general inflation.

Taken together, all things being equal, adding roughly 1,000 plumbers would reduce overall costs for plumbing services by just over $77.4 million annually. This would be spread across a wide range of economic activities, all of which use plumbing services either for new construction or maintenance. The savings would not come from the pockets of plumbers themselves. Average wages would fall by just $300 per plumber, or by about $2.6 million in the average state with about 8,800 plumbers. This means that the bulk of these cost reductions would be borne by contractors, plumbing company owners or other middlemen, not by the plumbers themselves. This is because plumbing services are not optimally priced due to the shortage of plumbers.

Economic Impact of Lower Service Costs

The data suggest that overall plumbing costs in the country could be reduced by over $77.4 million annually if 100,000 new plumbers were trained and available to work. The total number of unemployed people currently available to work in the United States as of December 2021, was just over 6.3 million, meaning that nearly 4.4 percent of all unemployed persons would need to opt to become plumbers to cover the total shortfall.[8] Currently, about 0.26 percent of the labor force are plumbers. Assuming that this same percentage were to apply to the available number of potential workers, it would be more realistic to think that 16,400 people might be willing and ready to join the plumbing sector.

The addition of 16,400 new plumbers would be expected to reduce plumbing costs by nearly $1.271 billion, of which $1.126 billion would be savings on new construction costs, and $144.499 million in savings on maintenance costs on existing plumbing infrastructure.

These savings in plumbing new construction and maintenance costs were distributed based on estimated past plumbing spending in new construction and maintenance, respectively.

IMPACT MODEL

The analysis utilizes the IMPLAN model to calculate economic impacts.[9] The model adopts an accounting framework to compute the relationships between different inputs and outputs across industries and sectors. This model can show the impact of a given economic decision – such as a retailer opening– on a pre-defined, geographic region. It is based on the national income accounts the US Department of Commerce, Bureau of Economic Analysis (BEA) generated.[10]

The IMPLAN model is designed to run based on the input of specific direct economic factors. Based on these entries, it generates estimates of the other direct impacts, tax impacts, and supplier and induced impacts. In the case of this model, estimated changes in the amount of pluming cost savings allocated across industries is a starting point for the analysis.

Once the higher costs have been established, they are entered into a model linked to the IMPLAN database based on the percentage of spending in each IMPLAN code in every state over the total US spending for either new construction or maintenance. This distributed savings data was then run through IMPLAN as a loss of output.

The IMPLAN data are used to estimate employment, direct wages and output. Wages are derived from the U.S. Department of Labor's ES-202 reports. IMPLAN uses this data to provide annual average wage and salary establishment counts, employment counts, and payrolls at the county level. Since this data only covers payroll employees, it is modified to add information on independent, agricultural, construction, and certain government employees. Data are then adjusted to account for counties where non-disclosure rules apply. Wage data include cash wages, health and life insurance payments, retirement payments and other non-cash compensation. In short, it includes all income paid to workers by employers.

Total output is the value of production by industry in a given state. IMPLAN estimates it from sources similar to those used by the Bureau of Economic Analysis (BEA) in its RIMS II series. Where no Census or government surveys are available, IMPLAN uses models such as the Bureau of Labor Statistics' growth model to estimate the missing output.

The model also includes information on income received by the Federal, state, and local governments and produces estimates for the following taxes at the Federal level: Corporate income; payroll, personal income, estate and gift, customs duties; and fines, fees, etc. State and local tax revenues include estimates of: Corporate profits, property, sales, severance, estate and gift and personal income taxes; licenses and fees and certain payroll taxes.

IMPLAN Methodology[11]

Input-output analysis, for which Wassily Leontief received the 1973 Nobel Prize in Economics for, is an econometric technique used to examine the relationships within an economy. It captures all monetary market transactions for consumption in a given period and for a specific geography. The IMPLAN model uses data from many sources– published government data series, unpublished data, sets of relationships, ratios, or estimates. IMPLAN gathers this data, converts them into a consistent format, and estimates the missing components.

There are three different levels of data generally available in the United States: federal, state, and county. Most of the detailed data are available at the county level, but there are many disclosure issues, especially in smaller industries. IMPLAN overcomes these disclosure problems by combining a large number of datasets and estimating variables that are not found in the merged data. The data are then converted into national input-output matrices (Use, Make, By-products, Absorption, and Market Shares) as well as national tables for deflators, regional purchase coefficients, and margins.

The IMPLAN Make matrix represents the production of commodities by industry. The Bureau of Economic Analysis (BEA) Benchmark I/O Study of the US Make Table forms the bases of the IMPLAN model. The Benchmark Make Table is updated to current year prices and rearranged into the IMPLAN sector format. The IMPLAN Use matrix is based on estimates of final demand, value-added by sector, and total industry and commodity output data as provided by government statistics or estimated by IMPLAN. The BEA Benchmark Use table is then bridged to the IMPLAN sectors. Once the re-sectoring is complete, the Use tables can be updated based on the other data and interstate and international trade model calculations.

In the IMPLAN model, as with any input-output framework, all expenditures are in terms of producer prices. This allocates all expenditures to the industries that produce goods and services. As a result, all data not received in producer prices are converted using margins derived from the BEA Input-Output model. Margins represent the difference between producer and consumer prices. As such, the margins for any good add up to one.

Deflators, which account for relative price changes during different time periods, are derived from the Bureau of Labor Statistics (BLS) Growth Model. The 224 sector BLS model is mapped to the 544 sectors of the IMPLAN model. Where data are missing, deflators from BEA's Survey of Current Businesses are used.

Finally, the Regional Purchase Coefficients (RPCs) – essential to the IMPLAN model – must be derived. IMPLAN is derived from a national model, representing the "average" condition for a particular industry. Since national production functions do not necessarily represent particular regional differences, adjustments need to be made. Regional trade flows are estimated based on the Multi-Regional Input-Output Accounts, a cross-sectional database with consistent cross interstate trade flows. These data are updated and bridged to the 544 sector IMPLAN model.

Once the databases and matrices are created, they undergo extensive validation. IMPLAN builds separate state and county models and evaluates them, checking to ensure that no ratios are outside of recognized bounds. The final datasets and matrices are not released until extensive testing takes place.

Model Results

Note that while the analysis calculates these impacts at the state and national level, only the national results are presented in this paper. State-level data are available directly from JDA.

Construction

A savings of $1.271 billion in plumbing expenses is expected to lower the cost of new building construction by $1.126 billion, with the remainder representing lower maintenance costs. Spread across industries utilizing new construction services, the economic impact of these savings would be over 29,100 new FTE jobs, paying workers $622.7 million in wages and benefits. In addition, companies supplying goods and services related to all of the new production and sales resulting from lower construction costs would add 895 more jobs, and the multiplier effect from the re-spending of additional wages would add another 5.600.

TABLE 4
THE ECONOMIC BENEFIT OF 16,400 ADDITIONAL PLUMBERS RESULTING FROM LOWER CONSTRUCTION COSTS

	Jobs	Wages	Output
Direct	29,109	$622,730,800	$1,261,216,900
Supplier	895	$67,957,600	$230,508,600
Induced	5,599	$325,472,900	$1,035,303,800
Total	35,603	$1,016,161,300	$2,527,029,300
Federal Taxes			$217,954,600
State and Local Taxes			$148,688,000
Total Taxes			$366,642,600

Overall, the $1.261 billion savings in plumbing construction expenses resulting from the addition of 16,400 new plumbers to the US markets would grow the economy by $2.5 billion and generate 35,600 additional jobs throughout all parts of the economy, paying over $1.0 billion in wages.

Governments would also benefit from the resulting new activity, receiving $366.6 million in additional business and personal taxes.

Maintenance

A savings of $1.271 billion in plumbing expenses would lower the cost of maintenance plumbing by $144.5 million. Spread across industries utilizing plumbing services, the economic impact of these savings would be nearly 750 new FTE jobs, paying workers $34.1 million in wages and benefits. In addition, companies supplying goods and services related to the new production and sales resulting from lower costs would add 670 more jobs, and the multiplier effect from the re-spending of additional wages would add another 603. Overall, the $144.5 million savings in plumbing maintenance expenses resulting from the addition of 16,400 new plumbers to the US markets would grow the economy by $422.1 million and generate 2,021 additional jobs throughout all parts of the economy, paying over $116.5 million in wages.

TABLE 5
THE ECONOMIC BENEFIT OF 16,400 ADDITIONAL PLUMBERS RESULTING FROM LOWER MAINTENANCE COSTS

	Jobs	Wages	Output
Direct	748	$34,145,000	$155,563,400
Supplier	670	$45,020,500	$147,928,400
Induced	603	$37,336,600	$118,644,100
Total	2,021	$116,502,100	$422,135,900
Federal Taxes			$24,104,300
State and Local Taxes			$16,853,800
Total Taxes			$40,958,100

Governments would also benefit from the resulting new activity, receiving $41.0 million in additional business and personal taxes.

Total

Taken together, reduced plumbing expenses for both maintenance and new construction would have a significant beneficial impact on the US economy, not only directly creating nearly 29,860 new FTE jobs throughout the country, but also leading to 7,770 additional jobs as a result of the multiplier effects and savings pass through to wage and other business expenses.

These 37,624 new jobs would pay workers over $1.1 billion in wages and benefits and grow the economy by nearly $3.0 billion in total. Finally, the federal government could see $242.1 million in additional business and personal taxes, while state and local treasuries would benefit to the tune of $165.5 million.

TABLE 6
THE ECONOMIC BENEFIT OF 16,400 ADDITIONAL PLUMBERS, TOTAL

	Jobs	Wages	Output
Direct	29,857	$656,875,800	$1,416,780,300
Supplier	1,565	$112,978,100	$378,437,000
Induced	6,202	$362,809,500	$1,153,947,900
Total	37,624	$1,132,663,400	$2,949,165,200
Federal Taxes			$242,058,900
State and Local Taxes			$165,541,800
Total Taxes			$407,600,700

DISCUSSION

We find a negative correlation between plumber availability (the number of plumbers) and average annual plumber wages. This fits with our assumption that a shortage of skilled labor would be consistent with higher plumbing prices. Moreover, this reflects the price elasticity of demand for plumbing services. The coefficient on the number of plumbers indicates that for every additional 1,000 plumbers, the average wage of plumbers would drop about $300 annually.

While the wage premium is only one of the effects of the skilled labor shortage, its impact adds up. As the second model shows, these higher costs are passed through to nearly every sector of the economy, not only through higher costs for constructing new factories, offices, commercial establishments, and homes, but also maintaining these facilities once occupied.

The plumber shortage is a microcosm of the overall skilled labor shortage, and there are policies that might be undertaken to encourage greater participation in these roles. First and foremost, there is a stigma around the pursuit of trades careers that can be addressed with awareness programs and a reintroduction of shop class in high school curricula. The college-or-bust archetype comes from a well-intentioned perspective that continued higher education presents a greater variety of opportunities and options for those who complete the journey; however, college costs have been increasing over the last few decades, and a greater number of students are undertaking larger and larger quantities of debt to pursue their studies.

Another perceived drawback of trades-related employment is the physical toll certain jobs or tasks may take on one's body. Plumbers and similar trades workers often deal with dangerous materials, lift heavy loads of equipment, contort into awkward or unnatural positions for periods, and work long hours. Policies that protect workers, physically and financially, might induce higher entry into the trade's workforce. To some extent, physical education and basic financial math might help with some of these aspects, which could be included in high school or trade school curricula.

Finally, due to data constraints, and the onset of COVID-19 and its substantial effects on the economy, the model is limited to the period from 2010 to 2018. Further research would be necessary to determine if the effects of the plumber shortage have persisted.

CONCLUSION

The skilled labor shortage has been an issue looming in the U.S. labor market for decades. Still, recent increased demand in building and the retirement phase of the baby boom cohort makes the resulting inefficiencies all the more concerning. We have shown in this research the effect of the shortage on plumber wages.

The skilled labor shortage does not just impact construction and maintenance-related industries.

We do not suggest that it is the role of the government to assign jobs, or to set wages. However, we suggest that the importance of skilled trades be conveyed in secondary education, and lawmakers consider ways to involve trades in the classroom. This may familiarize younger Americans with skills and tools in which they may find interest or for which they may have some hidden untapped skill or aptitude. Moreover, familiarizing younger generations with the trades may help destigmatize whole career pathways, which have taken a backseat as higher ed has tended to focus (in recent decades) on bachelor's degrees.

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ENDNOTES

1. U.S. Bureau of Labor Statistics, *Occupational Employment and Wage Statistics*. https://data.bls.gov/oes/#/home. Data Accessed December 2022. Data for “Plumbers, Pipefitters, and Steamfitters” (SOC Code 472152) across all industries, private and government employment.
2. *Occupational Outlook Handbook, Plumbers, Pipefitters, and Steamfitters*, US Department of Labor, Bureau of Labor Statistics at https://www.bls.gov/ooh/construction-and-extraction/plumbers-pipefitters-and-steamfitters.htm (accessed May 15, 2023).
3. See for example: Farrington, Robert, *Trade Schools Vs. Traditional College: What You Should Know*, Forbes, February 21, 2022, at: https://www.forbes.com/sites/robertfarrington/2022/02/21/trade-schools-vs-traditional-college-what-you-should-know/?sh=57c8d92b7638.
4. Based on data from the IMPLAN models for the years 2010 through 2018.
5. IMPLAN® model, 2018 Data, using inputs provided by the user and IMPLAN Group LLC, IMPLAN System (2023), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078, www.IMPLAN.com. Note that data for years 2010, 2012, 2014, 2016, and 2018 were used in the analysis.
6. Bureau of Labor Statistics, *Quarterly Census of Employment and Wages*. Contractor employment is the sum of employment in NAICS sectors 236115, 236116, and 236118. Data retrieved January 2022
7. *Producer Price Index by Commodity: Special Indexes: Construction Materials*, US Bureau of Labor Statistics, December 2021, retrieved from FRED, Federal Reserve Bank of St. Louis, at: https://fred.stlouisfed.org/series/WPUSI012011.
8. *Unemployment Level*, US Bureau of Labor Statistics, December 2021, retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/UNEMPLOY.
9. The model uses 2018 input/output accounts.
10. The IMPLAN model is based on a series of national input-output accounts known as RIMS II. These data are developed and maintained by the U.S. Department of Commerce, Bureau of Economic Analysis as a policy and economic decision analysis tool.
11. This section is paraphrased from IMPLAN Professional: Users Guide, Analysis Guide, Data Guide, Version 2.0, MIG, Inc., June 2000.

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