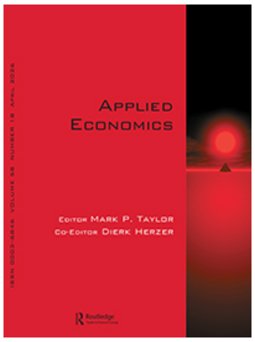

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Stay healthy, stay employed: how flu vaccination might impact women's earnings

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ABSTRACT

This paper examines the effects of state-level adult and child seasonal flu vaccination rates on hourly real wages for women. Using an IV method to address possible endogeneity, we find a significantly positive effect of adult vaccination on women's wages. Furthermore, we show that this effect is stronger for working mothers in age groups 16–24 and 25–44, and those with younger children aged 6 months–12 years. We also find that children's vaccination has a significantly positive effect on mothers' wages and that this effect is stronger for women with younger children. The results also show that the positive effect is particularly larger for non-college educated women, aged 16–44 with at least one child. These effects are also stronger for mothers with younger children.

KEYWORDS

Seasonal influenza; vaccination; wages; women; education level; national paid sick leave program

JEL CLASSIFICATION

I12; I18; J13; J31

I. Introduction

Virus epidemics can significantly hamper economic activity.[1] Mass vaccination helps mitigate these costs by limiting outbreak intensity and supporting recovery. Studies show flu vaccination is cost-effective, reducing work absenteeism (Nichol 2001; White 2021), morbidity, and mortality (Ward 2014), while providing wage benefits (Lee et al. 2002). However, its effect on wages remains understudied, particularly across demographic groups. This study examines the effects of adult and child seasonal flu vaccination rates on state-level average hourly real wages for U.S. women from 2010 to 2019.[2] We specifically analyse heterogeneity across age, childbearing status, children's age, and education levels.

The US offers a compelling case study for examining the labour market effects of flu vaccination. U.S. routine vaccination rates – including diphtheria, tetanus, pertussis, measles, and hepatitis B – consistently rank below the OECD average. For instance, the US COVID-19 full vaccination rate reached only 66.72% by June 2022, ranking 22nd among 38 OECD nations (Mathieu et al. 2020). This shortfall is projected to exert substantial negative labour market pressure across short-, medium-, and long-term horizons (A. Bartik et al. 2020; Gupta et al. 2023).

Second, the US is an outlier regarding health-related labour market policies, aggravating the potential economic costs of low vaccination rates. The US and Korea are the only OECD countries without a statutory paid-sick leave system, which worsens the financial burden of illness for workers (OECD 2020). In fact, only 25% of firms in the US offered paid parental leave in 2019 (KFF 2019). As of 2021, 14 states, plus Washington, DC, and 20 cities, have passed laws requiring paid sick leave for parents or their sick children; nine states and DC have passed laws for paid family leave (KFF 2021). This policy heterogeneity translates into significant differences in women's economic outcomes by state, especially for mothers with young children. Women in states without paid leave are disproportionately employed in low-paid hourly jobs without employer-provided benefits, often experience

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[1]The COVID-19 pandemic caused an unprecedented recession, with 83.9 million cases and over 1 million US deaths by June 2022 (WHO 2021). Seasonal influenza imposes an annual US economic burden between $34.7 and $87.1 billion, accounting for 610,660 life-years lost and 31.4 million outpatient visits (Molinari et al. 2007; Rothman 2017).

[2]The sample ends in December 2019 to exclude COVID-19 confounding effects.

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immediate wage losses, and are more likely to reduce work hours when they need time off for family illness. Part-time workers and workers with lower-skill jobs have significantly lower access to paid sick leave policies (KFF 2017).[3]

Third, vaccination's labour market effects likely vary across states due to significant internal and cross-state heterogeneity in conditioning factors (Bernstein et al. 2016). For instance, as of October 2022, full-dose COVID-19 vaccination rates ranged from 84% in Rhode Island to 52% in Alabama (Times 2022). Similar disparities persist in other immunizations, including the seasonal flu. Furthermore, state-level legal frameworks regarding paid sick and family leave exhibit substantial variation.

In addition to state-specific factors, we expect the effects of vaccination on labour market dynamics to be heterogeneous across different populations based on gender, age, family status, and education levels. For example, we expect families with children to be more sensitive to vaccination uptake as they face financial constraints that prevent them from taking unpaid leave from work to vaccinate their children or take care of their sick children, especially given the lack of a federal individual or family paid sick-leave programme (Choudhury and Polachek 2021). Paid sick leave is crucial because it is found to significantly increase job retention and reduce personal financial burden (Veenstra et al. 2015), and increase employment probabilities and work hours per week for mothers during their child's second year of life (Baum and Ruhm 2016).[4] The lack of paid family leave policies affects women more than men. Women are expected to face a disproportionate burden because of a sick child, given that they are significantly more likely to be primary caregivers (Piper et al. 2017). Women are found to face more negative labour market outcomes, including employment and work hours, than men when confronted with disease or pandemics (Brodeur et al. 2021).[5]

Given state-level heterogeneity in vaccination uptake, public health policies, and labour laws, empirical evidence on the magnitude of flu vaccination's labour market effects remains limited. Previous research shows that pandemic outbreaks adversely affect both consumption and production. For example, Carillo and Jappelli (2022) found that the 1918 Great Influenza caused a 6.5% decline in Italy's regional GDP per capita growth. Barro, Ursúa, and Weng (2020) and Masia et al. (2018) report similar effects of vaccination on GDP. Acemoglu and Johnson (2007) estimate that a 1% increase in life expectancy, attributed largely to post-1940 s vaccines, leads to a 1.7% to 2% population increase and a 0.43% to 1.17% rise in GDP.[6]

We show that mothers, especially those who have young children, face greater difficulties during periods of illness, disrupting both their caregiving duties and labour supply. Furthermore, we find that vaccination mitigates these disruptions by reducing illness incidence, thereby increasing hours worked. This mechanism is especially relevant for mothers, who typically bear the primary burden of caregiving when children are sick. Consequently, by reducing flu-like illness, vaccination allows mothers of young children to maintain a stable work schedule and productivity, yielding disproportionate gains for them in the labour market.

As for human capital and labour market effects, Ward (2014) estimates the spillover effects of the Ontario Universal Influenza Immunization Campaign. The findings show considerable effects: a reduction in 9 deaths per 100,000 population, a 48% decline in the incidence of pneumonia and influenza, and a 14% decrease in work absenteeism. Moreover, in terms of monetary costs and benefits, Ward (2014) finds that annually, the programme costs only $33 million and benefits society by sav-

[3]For more details on the US's paid sick leave policies and their comparison to other OECD countries, please see Section A1 in Online Appendix A. As shown in Figure A1, only a minority of states had enacted comprehensive paid sick and medical leave legislation as of 2021, with these policies concentrated primarily along the West Coast and in the Northeast. In contrast, the vast majority of states spanning the South, Midwest, and Mountain West regions lack statewide paid sick and medical leave mandates, leaving workers in these regions dependent on voluntary employer policies or entirely without access to such benefits.

[4]The previous literature has documented a persistent and long-run wage penalty for women after childbirth, causing lower wages, fewer hours of work, and lower employment and labour force participation (Rossin-Slater 2017).

[5]Racial disparities also are likely to play a significant role as African-Americans are found to have a significantly lower flu vaccination rate than whites (Egede and Zheng 2003).

[6]A few studies also fail to find a significant relationship between pandemics and growth (Bloom and Mahal 1997).

ing \$171–\$241 million. Similarly, White (2021) measures the social and external benefits of flu vaccination and finds that it significantly reduces illness-related work absences. Akazawa, Sindelar, and Paltiel (2003), for example, report that the mean number of workdays missed due to flu-like illnesses (FLI) in the US is 1.30 days. Likewise, Nichol (2001) finds that vaccinating adult U.S. workers against influenza allows significant cost savings through the illness rate, hourly wages, and work absenteeism. Similarly, Lee et al. (2002) find significant wage benefits from seasonal flu vaccination.

To the best of our knowledge, this is the first paper to examine the heterogeneous effects of influenza vaccination across socio-demographic groups. We complement the previous literature by exploring the labour market effects of adult and child flu vaccination rates on state-level monthly real hourly wages of women, as well as mothers by parental status. Our identification strategy uses Bartik-style instrumental variables that exploit flu infection rates across time by age groups and the local age composition. The underlying logic of our instrument is that last year's flu severity, which differed across age groups, interacts with state demographic composition to generate exogenous variation in this year's vaccination rates.

Based on OLS and IV estimation methods, the empirical results suggest that both adult and child flu vaccinations have a significantly positive effect on average monthly earnings. However, this effect is not homogeneous across demographic groups defined by age and education level, and is primarily driven by its impact on female workers aged 16–44 with at least one child. Furthermore, this positive effect is greatest among mothers with younger children. The skill level also matters, and vaccination has the largest positive effect on women with non-college education. These results are robust to a variety of sensitivity tests.

The rest of the paper is organized as follows. Section II introduces the data and empirical methodology, followed by section III, which presents and discusses the main empirical results.[7] Section IV concludes.

II. Empirical analysis

Data

To assess the effect of influenza vaccination on wages, we used the period from January 2010 to December 2019, just before the onset of the COVID-19 pandemic, thereby isolating the effects of influenza vaccination from those of COVID-19. The data for flu vaccination rates are from the CDC's FluVaxView (CDC 2021a), which provides monthly state-level vaccination rates for four age cohorts (6 months to 4 years, 5 to 12 years, 13 to 17 years, and 18 to 64 years). We use the IPUMS CPS data for monthly estimates of average hourly wages by age, number of children, and education level (Flood et al. 2021). State-level controls, including unemployment, education, absenteeism, marital status, and race, are also obtained from the IPUMS CPS. Quarterly state-level real GDP data are from the Bureau of Economic Analysis (BEA 2021). Finally, we instrument for 'Hours of Work' using vaccine adverse events data from CDC Wonder (CDC 2021b) and the Vaccine Adverse Event Reporting System (CDC, and FDA 2022).[8]

Empirical specification and methodology

The reduced form specification we adopt in Eq. (1) is from the standard Mincer Earnings equation (Mincer 1958).[9] The regression equation is as follows:

$$lnWage_{imt} = \alpha + \beta Vaccination_{imt} + X_{imt}\theta + \eta_i + \gamma_m + \varepsilon_{imt}, \tag{1}$$

where the dependent variable, $lnWage_{imt}$, is the (log) average hourly real wage for women in state i and month m in a year t.[10] We use state-level monthly CPI to convert nominal values to real values. η_i represents state fixed effects, measuring

[7]Section A2 in the Online Appendix A provides a conceptual framework for the empirical analysis, and Section A4 reports the sensitivity analysis.

[8]An adverse event is a possible side effect reportedly caused by a vaccine. The descriptive analysis in Section A3 in the Online Appendix A presents a detailed description of the data and accompanying summary statistics.

[9]The Conceptual Framework for the effect of vaccination rate on wages is discussed in Section A2 in Online Appendix A.

[10]Hence, the dependent variable, $lnWage_{imt}$ does not measure average monthly earnings. We also exclude salaried workers because their imputed hourly wages do not change when work is missed, and including them would underestimate the effects of flu vaccination on wages.

any time-invariant differences across states; γ_m denotes the month fixed effects, and ε_{imt} are the unobserved error terms. The standard errors are clustered at the state level.

Our primary control variable, $_{imt}$ Vaccination $_{imt}$, is the monthly (m) flu vaccination rate of different age-specific sub-groups in state i in a - given year t. As discussed in Online Appendix A, Section A2, we expect higher vaccination rates to raise average wages, as workers will be less likely to become ill and take unpaid time off. We note that the adult vaccination rate is reported for both women and men due to the lack of state-level gender-specific data. Therefore, our estimated coefficients capture the effect of increases in the overall adult vaccination rate on women's labour market outcomes. This effect represents both direct protection of women and indirect protection through vaccinated household members, including children. However, previous studies using survey data suggest that women have a significantly higher flu vaccination rate, and therefore, our identification here is biased against finding a significant effect. In other words, the results reported here can be taken as the lower bounds of the estimated effects (Ward 2014).

In addition, X_{imt} includes a full set of monthly state-level controls:

$ln(W_{i(m-1)t})$ is the one-month lagged dependent variable, average hourly real wage, and controls for the dynamic wage adjustment over time.

$RGDP_{i(m-4)t}$ is the (one-quarter lagged) quarterly real gross state GDP growth and controls for the effect of growth and market demand for labour.

$High-School_{imt}$ is the fraction of the high-school graduates population in a given state and month, and controls for the effect of low-skill human capital education on wages.

$College_{imt}$ is the fraction of the college graduates population in a given state and month, and controls for the effect of high-skill human capital education on wages.

$African-American_{imt}$ is the fraction of the African American population in a given state and month, and controls for the negative wage penalty African American workers experience in the US labour market.

$Unemployment_{i(m-1)t}$ is the one-month lagged state-level unemployment rate and controls for the effect of unemployment on wages through loss of workers' bargaining power and labour market tightening. We should note that real GDP growth also partly captures this effect; therefore, we may be underestimating the full effect of unemployment on wages.

To help compare our study with previous research, we first estimate Eq. (1) with the ordinary least squares (OLS) method. However, there are several well-justified concerns with this approach. First, the state-level vaccination rate depends on many variables related to wages and vaccination rates, which are not observable in the CDC and CPS survey data.[11]

Therefore, to better identify the causal effect of the vaccination rate on wages, we employ an instrumental variables (IV) strategy that accounts for potential endogeneity. The ideal IV for the vaccination rate to estimate Eq. (1) should only be driven by some exogenous variation in health outcome variables and satisfy both the relevance and exclusion conditions. Specifically, the exclusion restriction requires that the IV affects wages only through its impact on vaccination rates and not through any direct or omitted channels. This is particularly challenging given the potential confounding mechanisms, such as unobserved differences in state policy environments, healthcare infrastructure, or population health, which may affect both vaccination rates and economic outcomes. Therefore, the potential concerns arise if the IV is correlated with omitted variables such as institutional trust, political ideology, or population health, which are correlated with both vaccination behaviour and labour

[11]The US National Immunization Surveys (NIS) data are individual-level but do not have wage or income variables. For example, vaccine hesitancy is partially driven by ideological, religious, and political beliefs, which also shape preferences for labour market participation. These factors are latent but correlated with both vaccination rates and labour supply decisions and wages. Furthermore, States differ in public health infrastructure in terms of the quality of healthcare services and the efficiency of logistical operations. These factors are not captured in CPS and CDC data but can influence both vaccination rates and labour market outcomes, potentially introducing endogeneity. Second, higher wages may help vaccination by alleviating time constraints, improving access to healthcare, and increasing the likelihood of paid sick leave. As a result, wages may also affect vaccination rates, introducing the possibility of reverse causality. Third, CDC and CPS data are based on self-reported responses, and small errors in survey reporting may be amplified in state-level aggregates, introducing attenuation bias.

market participation; the exclusion restriction may be violated.

To find an instrumental variable, we predict the state-level flu-like illnesses for a given year using the age composition of a state's population and use the lag of that predicted flu-like illnesses variable as an instrument for a state's vaccination rate. First, we describe the measure of our instrumental variable and then provide our intuition for the choice of this instrument. Following T. J. Bartik (1991), we construct the following measure of state-level predicted flu-like illnesses ($\widehat{FLI}$) in a given month m and year t:

$$\widehat{FLI}_{ait} = \sum_{at}\left(\omega_{ait} \times \widetilde{FLI}_{US,a,t}\right) \text{where } \omega_{ait} = \frac{pop_{ait}}{\sum_a pop_{ait}} \tag{2}$$

where the subscript a denotes an age group, i represents state and pop denotes population. $\widetilde{FLI}_{US,a,t}$ denotes the US average number of flu-like illnesses of age group a in year t, and ω_{ait} denotes the population share of age group a in state i at year t. Specifically, we use four age groups: (i) 6 months–4 years, (ii) 5–12 years, (iii) 13–17 years, and (iv) 18–64 years.[12] In practice, this yields four instruments, corresponding to each age-specific vaccination rate (adult and three child age groups), constructed in an analogous manner. Instead of the current year's predicted flu-like illnesses ($\widehat{FLI}_{ait}$), we use one year lag, $\widehat{FLI}_{ai(t-1)}$ as an instrument for flu vaccination rate of a state because if more people affected by flu last year, we expect a majority of them will take flu vaccine in the current year.[13]

The intuition for our choice of IV is that the vaccination rate in a state is positively associated with last year's predicted flu-like illnesses. Furthermore, it is very unlikely that the previous year's predicted flu-like illnesses directly affect the subsequent year's wages.[14] Therefore, in the first stage of the IV approach, we expect a strong positive correlation between the previous year's predicted flu-like illnesses and the current year's flu vaccination rate. We report under-identification test results based on the Kleibergen-Paap LM Statistic to address concerns regarding weak-instrument problems and the first-stage F-statistic.

The exclusion restriction requires that the Bartik instrument $\widehat{FLI}_{ai(t-1)}$ affects wages (W_{it}) only through the vaccination rate V_{imt}. A possible threat to this condition is that age composition of the population, ω_{ait} is correlated with the unobserved error terms in Equation (1). Borusyak, Hull, and Jaravel (2022) argue that under certain regularity conditions, the identification of this Bartik instrument is achieved when $\widetilde{FLI}_{US,a,t}$ is uncorrelated with the local labour market's unobserved demand shocks, while ω_{ait} are allowed to be endogenous. Therefore, $\widehat{FLI}_{ai(t-1)}$ is most likely a valid instrument since we do not expect $\widetilde{FLI}_{US,a,t}$ to be correlated with the error terms ε_{imt}.

Furthermore, Borusyak and Hull (2023) develops an estimation method to address whether $\widehat{FLI}_{ai(t-1)}$ is not fully exogenous. This can happen if an unobserved labor demand shock for any state is correlated with $\widetilde{FLI}_{US,a,t}$. To address this concern, following Borusyak and Hull (2023) we estimate the following re-centered instrument,

$$\begin{aligned}\widetilde{FLI}_{ait} &= \widehat{FLI}_{ait} - \mu_{ait} \text{ and } \mu_{it} \\ &= \frac{1}{N!}\sum_{\pi(\cdot)\in\Pi_N} f\left(\pi\left(\widetilde{FLI}_{US,a,t}\right); \omega_{ait}\right)\end{aligned} \tag{3}$$

where N is the dimension of $\widetilde{FLI}_{US,a,t}$ and $f(\cdot) = \omega_{ait} \times \widetilde{FLI}_{US,a,t}$. We perform 1,000 permutations to calculate the expected state-level flu vaccination rates. We then subtract the expected instrument to obtain the re-centered instrument and take a one-year lag $\widetilde{FLI}_{i(t-1)}$. The results are reported in the Online Appendix Table D1.[15] As shown in columns 1–3, the estimates of the flu vaccination rate from the re-centred instrument

[12]This is because we want to be consistent with the age groups we used for the flu vaccination.

[13]As a robustness check for the validity of the instrument, we use the flu infection rate from two years prior (t-2) as an alternative instrument for vaccination rates and report the results in the Online Appendix Table D10 (second-stage) and D11 (first-stage). The estimates remain stable across specifications, indicating that the two-year lag supports the validity of the one-year lag instrument.

[14]This is based on the assumption that last year's flu infections have no direct effect on this year's labour market outcomes. This is consistent with CDC evidence showing that influenza is typically short-lived, with long-term complications rare and largely confined to high-risk groups, making persistent effects on working-age adults very unlikely.

[15]The first stage results for the recentered IV are shown in Table D2.

Table 1. Impact of adult flu vaccination rate on state-level hourly real wage of women, 2010–2019.

	All Women		Women With At Least One Child		Women With At Least One Child < 5	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Vaccination-1864 $_{i(m-1)t}$	0.001***	0.014***	0.001***	0.014***	0.002**	0.018***
	(0.000)	(0.001)	(0.000)	(0.002)	(0.001)	(0.003)
W $_{i(m-1)t}$	0.073***	0.045**	0.045***	0.028	−0.021	−0.026
	(0.019)	(0.020)	(0.014)	(0.017)	(0.017)	(0.019)
RGDP $_{i(m-4)t}$	0.167**	0.289***	0.160*	0.280***	0.273	0.405**
	(0.069)	(0.079)	(0.092)	(0.096)	(0.188)	(0.192)
High-School $_{imt}$	−0.792***	−0.372*	−0.906***	−0.490**	−1.098***	−0.580
	(0.124)	(0.187)	(0.188)	(0.214)	(0.370)	(0.369)
College $_{imt}$	1.328***	0.806***	1.320***	0.767***	2.023***	1.343***
	(0.164)	(0.218)	(0.230)	(0.283)	(0.341)	(0.431)
Married $_{imt}$	0.159	0.421**	0.064	0.303	−0.077	0.172
	(0.139)	(0.187)	(0.156)	(0.204)	(0.360)	(0.368)
African-American $_{imt}$	−0.077	−0.127	−0.275	−0.340	−0.322	−0.354
	(0.160)	(0.191)	(0.226)	(0.241)	(0.541)	(0.520)
Unemployment $_{i(m-1)t}$	0.330***	0.036	0.212*	−0.103	0.253	−0.171
	(0.094)	(0.139)	(0.114)	(0.149)	(0.284)	(0.308)
Constant	2.422***		2.592***		2.642***	
	(0.067)		(0.071)		(0.154)	
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value		0.000		0.000		0.000
KP Wald F-stat		169.7		170.6		163.5
R-Sq	0.110	−0.060	0.100	−0.030	0.050	−0.006
Obs	5,027	4,832	5,027	4,832	4,999	4,804

W is the state level monthly logged average hourly real wage. The subscripts *i* denote state, *m* represents month, and *t* indicates year. *Vaccination* − 1864 is the fraction of 18–64 age group who had flu vaccination in a given state and month. Both OLS and IV regressions are with robust standard errors (in parentheses) are clustered at the state level. *RGDP* refers to quarterly average growth rates. State FE and Month FE are state and month fixed effects, respectively. *,**, and *** refer to significance at 10%, 5% and 1% levels. For other variable definitions, refer to Table A1 in Online Appendix A.

are almost identical to the corresponding columns 2, 4, and 6 in Table 1.

III. Empirical results

In this section, we present the main results, discuss a potential mechanism, and examine heterogeneous effects. Because we lack gender-specific vaccination data, our estimates reflect population-level vaccination effects.

Main result

We present the benchmark results from Eq. (1) using the OLS and IV methods in columns (1) and (2) of Table 1, respectively.[16] All regressions in Table 1 include state and month-fixed effects. We find that the vaccination rate has an economically and statistically significant positive effect on average wages in both the OLS and 2SLS results.[17] The economic magnitude of the estimated β coefficients of 0.001 and 0.014 in columns (1) and (2) suggests that a 1% increase in adult flu vaccination rate is associated with a 0.1% (OLS) to 1.4% (2SLS) increase in state-level hourly wages for women.[18] As expected, the 2SLS estimate, which is our benchmark, is significantly higher than the OLS estimate, given that the OLS is subject to measurement error in vaccination rate and to a large set of omitted variables related to wage and vaccination rates within a state.[19]

[16]Section A4 in Online Appendix A reports the sensitivity analysis, including the use of additional IVs, addressing IV exclusion restriction and omitted variable bias by including additional covariates, checking sensitivity to outliers, checking sensitivity by US Regions, and a sub-sample of states with paid sick leave, and lastly, using alternative standard error specifications. The results remain robust across all sensitivity checks.

[17]We have also estimated models for men and found similar but less precisely estimated effects. The results suggest smaller and less consistent labour market gains for men, consistent with women bearing greater caregiving responsibilities.

[18]We interpret the estimated effects as short-term, one-year impacts rather than permanent earnings changes. Since the identification relies on year-to-year variation, it captures temporary recoveries in wages and hours following higher vaccination rates. Hence, the observed wage gains should be interpreted as annual effects sustained by continued vaccination rather than as permanent wage increases.

[19]Women with higher illness risk due to childcare, health conditions, or caregiving duties are more likely to vaccinate and also face constraints that lower earnings. These omitted variables in Equation 6 induce a negative correlation between vaccination and wages, yielding a downward-biased OLS estimate.

Eq. (D) (Section A2, Online Appendix A) shows that the effects of vaccination on women's wages are not homogeneous, and they vary over children's ages. These analytical findings are consistent with the existing literature, which shows that the homogeneity assumption is not necessarily true as women bear a larger share of childcare responsibilities due to societal pressures and uneven division of intra-household responsibilities among heterosexual couples (Jensen and McIntosh 2007; Piper et al. 2017). Thus, we expect that any healthcare-related absenteeism or missing workdays will hurt working mothers' wages more, including a larger negative effect on their productivity (Løkke 2008). Thus, in columns (3)–(6) of Table 1, we examine the sensitivity of point estimates in columns (1)–(2) to the experiences of working mothers. We analyse the heterogeneous effects of vaccination rate for women with at least one child in columns (3)–(4) and for women with at least one child who is younger than age five in columns (5)–(6) of Table 1.

We find that the effects of vaccination on wages for working mothers are identical to those for women overall in columns (4) and (2). However, the difference is particularly strong for working mothers with a child younger than five (column 6), where the point estimate increases from 0.014 in column (2) to 0.018 in column (6).

As for other control variables, we find some evidence of a wage hysteresis effect for the full population in column (2). We also find that college graduates earn a significant wage premium, while high school graduates and dropouts (the base group) face a wage penalty. GDP growth appears positive and significant, as expected. Marital status has a positive but mostly insignificant effect, while the fraction of the African-American population appears to have a negative but also insignificant effect. The lagged unemployment rate is significant only in the OLS regressions of columns (1) and (3).

In Table 1 (and all others), we check the relevance of our IV using Kleibergen and Paap (2006) under-identification test and weak instrument test based on the Kleibergen-Paap Wald test. The critical value of the Kleibergen–Paap Wald test statistic lies between 5.53 and 16.38. As shown, the *p*-values of the KP Wald under-identification test in columns (2), (4), and (6) are less than 0.05, suggesting that we reject the null hypothesis of zero correlation between the endogenous regressor, the vaccination rate, and our instrument $\widehat{FLI}_{i(t-1)}$. Hence, our instrument is not irrelevant. Furthermore, the Kleibergen-Paap Wald test statistics values in columns (2), (4), and (6) are above the critical value of 16.38. Hence, our instruments are not weak either.

In Table 2, we report the first-stage regression results for columns (2), (4), and (6) from Table 1, where the dependent variable is the adult flu vaccination rate, and the main independent variable is our IV, the 1-year lag of predicted flu-like illnesses, $\widehat{FLI}_{i(t-1)}$. Although the main dependent and independent variables are the same in columns (1)–(3) of Table 2 which corresponds to columns (2), (4), and (6) in Table 1, one of the control variables, one-month lagged wage ($W_{(m-1)t}$), is different for three groups, all women, women with at least one child, and women with at least one child less than 5 years old. Hence, we get marginally different OLS coefficients for adult flu vaccination rates in columns (1)–(3). In column (1), we show that the conditional correlation between $\widehat{FLI}_{i(t-1)}$ and the adult flu vaccination rate is 5.017, suggesting that last year's predicted flu-like illnesses positively affect the current year's adult flu vaccination rate. We also observe similar effects among women with at least one child and at least one child under 5 years old. The intuition behind the positive association between our instrument and the vaccination rate is that the incentive to avoid any adverse experience from the flu is greater when more people were severely affected by it last year.

Direct channel: hours of work

Given the lack of data on labour productivity by vaccination status and gender at the state level, in Table 3, we examine a possible channel through which vaccination can affect wages: the work hours. Given the direct link between illness, caring for sick children, and working hours and wages, especially in the absence of paid sick leave policies, we expect a significant positive relationship between vaccination and average working hours. The effect is expected to be stronger for women with younger

Table 2. (First stage of Table 1 estimates) Impact of adult flu vaccination rate on state-level hourly real wage of women, 2010–2019.

	Women All	Women With At Least One Child	Women With At Least One Child < 5
	(1)	(2)	(3)
Bartik-Flu Like Illnesses $_{i(t-1)}$	5.017***	4.960***	4.904***
	(0.385)	(0.380)	(0.384)
W $_{i(m-1)t}$	−1.841***	−1.056**	−0.220
	(0.638)	(0.452)	(0.213)
RGDP $_{i(m-4)t}$	−17.710***	−17.666***	−17.317***
	(3.413)	(3.395)	(3.390)
High-School $_{imt}$	−9.085	−9.048	−10.647
	(10.167)	(10.219)	(10.324)
College $_{imt}$	−2.531	−2.918	−5.938
	(9.157)	(9.186)	(9.192)
Married $_{imt}$	−14.388	−14.562	−13.685
	(9.022)	(9.012)	(9.029)
African-American $_{imt}$	13.512	13.358	14.569
	(9.032)	(8.982)	(9.430)
Unemployment $_{i(m-1)t}$	10.842**	10.865**	10.200*
	(5.337)	(5.390)	(5.340)
State FE	Yes	Yes	Yes
Month FE	Yes	Yes	Yes
SW F test p-value	0.000	0.000	0.000
SW Chi-Sq p-value	0.000	0.000	0.000
Obs	4,832	4,832	4,804

Notes: *W* is the state level monthly logged average hourly real wage. The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) clustered at the state level. The construction of Bartik predicted Flu Like Illnesses variable is described in Eq. (2). *,**, and *** refer to significance at 10%, 5% and 1% levels. The columns (1), (2), and (3) in this table correspond to columns (2), (4), and (6) model specification in Table 1.

Table 3. Impact of adult flu vaccination rate on average hours of work of women, 2010–2019.

	Women All	Women With At Least One Child	Women With At Least One Child < 5
	(1)	(2)	(3)
Vaccination-1864 $_{i(m-1)t}$	0.026***	0.043***	0.071***
	(0.007)	(0.009)	(0.018)
H $_{i(m-1)t}$	0.515***	0.522***	0.488***
	(0.015)	(0.018)	(0.017)
RGDP $_{i(m-4)t}$	0.129	1.184**	1.426
	(0.505)	(0.561)	(1.308)
High-School $_{imt}$	−1.601*	−0.230	−1.105
	(0.936)	(1.327)	(2.214)
College $_{imt}$	3.571***	2.570*	2.596
	(1.033)	(1.402)	(2.422)
Married $_{imt}$	−1.150	0.246	−0.196
	(0.986)	(1.141)	(2.472)
African-American $_{imt}$	−1.849**	−2.240*	0.342
	(0.838)	(1.320)	(2.649)
Unemployment $_{i(m-1)t}$	−2.555***	−4.806***	−4.881**
	(0.784)	(1.310)	(1.980)
State FE	Yes	Yes	Yes
Month FE	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000
KP Wald F-stat	92.99	93.14	90.08
Hansen J p-value	0.791	0.0757	0.588
R-Sq	0.385	0.347	0.274
Obs	4,624	4,624	4,624

Notes: *H* is the state level average hours of work. The subscripts *i* denote state, *m* represents month, and *t* indicates year. Unlike Table 1, we used two instruments because the dependent variable in Table 3 is hours of work instead of hourly real wage. These two instruments are a one-year lag of predicted flu-like illnesses and a one-year lag of adverse events from the flu vaccine. The First stage of the 2SLS results are shown in Table 4. Since we have two instruments and one endogenous regressor, we report the Sargan-Hansen over-identification test results, which suggest that we cannot reject the null hypothesis that the two IVs are jointly exogenous at 5% significance level. IV regressions with robust standard errors (in parentheses) are clustered at the state level. *,**, and *** refer to significance at 10%, 5% and 1% levels.

children. Thus, using a standard reduced-form estimate from a similar type Mincer Equation (1), we examine the effects of the adult vaccination rate on the state-level average number of hours of work for women, including the standard set of control variables, and month and state fixed effects.

Our results suggest that the vaccination rate has a significantly positive effect on the average hours of work for women (column 1) and is stronger for women with at least one child (column 2), particularly when the child is younger than five (column 3). We know that missing workdays or hours imposes substantial costs on employers and employees, reducing workers' skill levels, harming workplace harmony, and decreasing productivity (Løkke 2008; Medina-Garrido, Biedma-Ferrer, and Sánchez-Ortiz 2020). Previous studies show that persistent missed workdays lead to the deterioration of workplace skills and generate conflicts among colleagues (Zhang et al. 2017). Additionally, employers experience reduced productivity and competitiveness. Thus, among other factors, vaccination is likely to affect wages through its effects on productivity (Quilici, Smith, and Signorelli 2015) and work hours.

In Table 4, we show the first-stage results from our 2SLS estimates from Table 3. As in Table 2, the main dependent variable is the adult vaccination rate, and the independent variable is the Bartik instrument. Because we have a different dependent variable in the second stage, hours of work, and also our model specification is slightly different than Equation (1), we have introduced one additional instrument besides Bartik IV, last year's predicted flu-like illnesses: 1-year lag of the number of adverse events (i.e. side effects) due to flu vaccination.[20] As shown in column (1) of Table 4, a year lag of the predicted number of flu-like illnesses is positively associated with women's hours of work. While the adverse events of the flu vaccine appear to have a negative impact on next year's flu vaccination rate, it is statistically insignificant. These results also hold for the other two groups, women

Table 4. (First stage of Table 3 estimates) impact of adult flu vaccination rate on average hours of work of women, 2010–2019.

	Women All	Women With At Least One Child	Women With At Least One Child < 5
	(1)	(2)	(3)
Flu Vaccine Adverse Events $_{i(t-1)}$	−0.032	−0.027	−0.024
	(0.161)	(0.159)	(0.159)
Bartik-Flu Like Illnesses $_{i(t-1)}$	4.955***	4.970***	4.888***
	(0.395)	(0.394)	(0.395)
W $_{i(m-1)t}$	−0.125	−0.114	0.062
	(0.137)	(0.089)	(0.039)
RGDP $_{i(m-4)t}$	−17.866***	−17.706***	−17.702***
	(3.151)	(3.175)	(3.103)
High-School $_{imt}$	−9.915	−10.150	−9.007
	(9.901)	(10.156)	(10.086)
College $_{imt}$	−4.627	−5.142	−5.312
	(9.532)	(9.360)	(9.244)
Married $_{imt}$	−16.664*	−16.724*	−16.015*
	(9.130)	(9.119)	(9.061)
African-American $_{imt}$	12.571	12.510	13.030
	(9.218)	(9.151)	(8.994)
Unemployment $_{i(m-1)t}$	9.665*	9.316*	10.672**
	(5.327)	(5.281)	(5.389)
State FE	Yes	Yes	Yes
Month FE	Yes	Yes	Yes
SW F test p-value	0.000	0.000	0.000
SW Chi-Sq p-value	0.000	0.000	0.000
Obs	4,624	4,624	4,624

Notes: *W* is the state level monthly logged average hourly real wage. The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) are clustered at the state level. *,**, and *** refer to significance at 10%, 5% and 1% levels. The columns (1), (2), and (3) in this table correspond to columns (2), (4), and (6) model specification in Table 3.

[20]Note that we add one additional instrument in Table 4 regression because the Bartik IV, $\widehat{FLI}_{ai(t-1)}$ cannot alone explain enough variation in the endogenous regressor, average hours of work, which is a different outcome variable than before.

with at least one child and women with at least one child under 5 years old.

Heterogeneous effects

Heterogeneity by age of children

As discussed earlier, given the lack of a national sick leave and family leave policy, together with state-level restrictions against leaving children unattended at home, our findings suggest that children's illness should directly affect parents' ability to work and, therefore, their earnings. We expect this effect to decrease with age and be strongest for younger children. Furthermore, if it is true that parents are likely to miss workdays to look after their children, we should be able to see this effect more strongly for parents in a specific (i.e. younger) age group. Thus, in Table 5, we explore the wage response heterogeneity to children's vaccination status by the age of vaccinated children in three subgroups, 6 months–4 years (columns (1)–(3)), 5–12 years (columns (4)–(6)), and 13–17 years (columns (7)–(9)). This exercise allows us to test directly the hypothesis that improving children's health conditions positively affects working mothers' wages.

Focusing on the IV results in Table 5, we find significant support for our earlier discussion on the connection between children's vaccination status and women's wages. First, we find that children's vaccination has a significantly positive effect on working women's wages. Second, independent of the age of vaccinated children, this effect is significantly larger for mothers with at least one child younger than five (columns (3), (6), (9)). Third, flu vaccination has the strongest effect on wages for women with children who are younger and aged 6-month-12 years (columns (1)–(6)) and is the weakest for those who are 13–17 years old (columns (7)–(9)). All these results are consistent with our analytical findings in Eq (4) (Section A2, Online Appendix A).

Overall, Table 5 results suggest that a 1% increase in vaccination rates for children aged 6 months–4 years and 5–12 years leads to approximately a 1.5% increase in wages for working

Table 5. Impact of child flu vaccination rate on state-level hourly real wage of women, 2010–2019.

	Women			Women			Women		
	All	At Least One Child	At Least One Child < 5	All	At Least One Child	At Least One Child < 5	All	At Least One Child	At Least One Child < 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vaccination-6M4YR $_{i(m-1)t}$	0.016***	0.017***	0.022***						
	(0.003)	(0.003)	(0.005)						
Vaccination-512 $_{i(m-1)t}$				0.015***	0.016***	0.020***			
				(0.002)	(0.002)	(0.004)			
Vaccination-1317 $_{i(m-1)t}$							0.010***	0.011***	0.013***
							(0.001)	(0.002)	(0.002)
W $_{i(m-1)t}$	0.046*	0.029	−0.020	0.028	0.025	−0.021	0.009	0.004	−0.029
	(0.024)	(0.019)	(0.020)	(0.022)	(0.018)	(0.021)	(0.020)	(0.019)	(0.019)
RGDP $_{i(m-4)t}$	0.500***	0.494***	0.745***	0.436***	0.419***	0.574**	0.471***	0.465***	0.621***
	(0.120)	(0.134)	(0.258)	(0.096)	(0.118)	(0.220)	(0.089)	(0.110)	(0.206)
High-School $_{imt}$	−0.325	−0.475*	−0.489	−0.350	−0.448	−0.537	−0.017	−0.113	−0.152
	(0.236)	(0.247)	(0.382)	(0.236)	(0.272)	(0.434)	(0.231)	(0.272)	(0.464)
College $_{imt}$	0.911***	0.870***	1.441***	0.695**	0.665*	1.130**	0.327	0.323	0.672
	(0.280)	(0.315)	(0.431)	(0.296)	(0.360)	(0.529)	(0.288)	(0.346)	(0.523)
Married $_{imt}$	0.335	0.235	0.068	0.703***	0.590**	0.565	0.957***	0.857***	0.841*
	(0.223)	(0.226)	(0.429)	(0.253)	(0.271)	(0.407)	(0.224)	(0.254)	(0.468)
African-American $_{imt}$	−0.075	−0.220	−0.242	0.147	−0.009	0.083	−0.002	−0.153	−0.085
	(0.237)	(0.322)	(0.627)	(0.206)	(0.284)	(0.536)	(0.172)	(0.287)	(0.581)
Unemployment $_{i(m-1)t}$	0.699***	0.602***	0.651*	0.898***	0.782***	0.909**	1.358***	1.251***	1.501***
	(0.160)	(0.173)	(0.371)	(0.166)	(0.193)	(0.386)	(0.160)	(0.201)	(0.373)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	57.09	54.43	52.53	99.17	101	99.11	111.2	106.7	108.6
R-Sq	−0.606	−0.346	−0.168	−0.424	−0.239	−0.109	−0.209	−0.096	−0.036
Obs	4,893	4,893	4,864	4,901	4,901	4,872	4,721	4,721	4,694

Notes: *W* is the state level monthly logged average hourly real wage. The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) clustered at the state level. *Vaccination − 6M4YR*, *Vaccination − 5 − 12* and *Vaccination − 13 − 17* refer to monthly state level vaccination rate for children aged 6 months–4 year, 5–12 year and 13–17 year, respectively. *,**, and *** refer to significance at 10%, 5% and 1% levels.

women and mothers. This effect jumps to around 2% for women with a child younger than five (columns (3) and (6)). This positive effect remains significant for older children aged 13–17 years but drops to 1–1.3%. These results likely reflect the effects of the absence of family leave policies, combined with legal restrictions on leaving younger children unattended. There is also a possible direct effect as unvaccinated children are likely to pass the flu to their parents, causing lost wages.

Heterogeneity by age of mother

The effect of vaccination on wages is likely to differ among working women of different ages, reflecting both job market and career development, and also parental status. Given the larger employment, wage, and working-hour effects of health shocks on younger workers, we expect that vaccination status will harm younger women more than older women. During the COVID-19 pandemic, for example, data suggest a greater decline in employment for younger workers (Montenovo et al. 2022). Table 6 shows the regression results for working women based on parental status and age. Focusing on the IV results in columns (1)–(3) in Table 6, we find that adult vaccination has a significantly positive effect on women for all age groups. However, the effect is the largest among younger workers (16–24) and smallest among older workers (45–65). Furthermore, we find significant differences within each group by parental status, likely reflecting the positive externalities of parental vaccination, reducing the likelihood that children, especially younger children, become ill (White 2021). Particularly, we find that women aged 16–24 and 25–44 with at least one child (columns 4 and 5) display significant wage responses to vaccination, while these effects are not present for the other age group 45–65 (columns (3) and (6)). The effects for women aged 16–24 and 25–44 with at least one child younger than five (columns (7)–(8)) are also quite similar to those in columns (4)–(5).

Heterogeneity by age of children for younger mother

Given the previous results, in Table 7 we focus on the effects of vaccination rates of children aged 6 months–4 years, 5–12 years, and 13–17 years on wages of working women and mothers for age groups 16–24 and 25–44 separately because a large fraction of women in these age groups have young children. Consistent with the results in Table 5, we find that the positive effects of

Table 6. Impact of adult flu vaccination rate on state-level hourly real wage by age and parental status, 2010–2019.

	All Women			Women With At Least One Child			Women With At Least One Child < 5		
	Age 16–24	Age 25–44	Age 45–65	Age 16–24	Age 25–44	Age 45–65	Age 16–24	Age 25–44	Age 45–65
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vaccination-1864 $_{i(m-1)t}$	0.023***	0.015***	0.010***	0.039***	0.015***	0.011***	0.037***	0.014***	−0.057
	(0.002)	(0.002)	(0.002)	(0.007)	(0.002)	(0.003)	(0.007)	(0.004)	(0.048)
W $_{i(m-1)t}$	0.077***	0.007	0.007	−0.039*	0.005	0.013	−0.065**	−0.028	−0.021
	(0.015)	(0.016)	(0.018)	(0.023)	(0.016)	(0.015)	(0.024)	(0.018)	(0.083)
RGDP $_{i(m-4)t}$	0.459***	0.450***	0.235**	−0.096	0.430***	0.088	−0.256	0.519***	−3.773*
	(0.152)	(0.082)	(0.104)	(0.474)	(0.113)	(0.149)	(0.513)	(0.193)	(1.882)
High-School $_{imt}$	−0.015	−0.434*	−0.486*	0.686	−0.528**	−0.417	0.039	−0.580	−0.785
	(0.326)	(0.222)	(0.253)	(0.805)	(0.227)	(0.353)	(0.760)	(0.397)	(3.822)
College $_{imt}$	1.121***	0.922***	0.688***	0.628	0.693**	0.580	0.228	1.059**	7.499
	(0.304)	(0.227)	(0.251)	(0.742)	(0.303)	(0.391)	(0.677)	(0.465)	(6.796)
Married $_{imt}$	−0.127	0.755***	−0.105	0.571	0.709**	−0.655**	0.591	0.116	−13.691**
	(0.289)	(0.281)	(0.214)	(0.760)	(0.290)	(0.298)	(0.805)	(0.485)	(6.637)
African-American $_{imt}$	−0.201	−0.044	−0.175	−1.073	−0.352	−0.416	−1.132	−0.454	−4.108
	(0.327)	(0.244)	(0.203)	(0.808)	(0.270)	(0.354)	(0.736)	(0.592)	(7.184)
Unemployment $_{i(m-1)t}$	−0.749***	0.237	−0.021	−1.147	0.181	−0.333	−1.095	0.103	2.838
	(0.229)	(0.169)	(0.169)	(0.727)	(0.181)	(0.243)	(0.728)	(0.334)	(3.488)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
KP Wald F-stat	154.2	157.6	163	95.91	158.7	163.9	95.84	161.6	19.65
R-Sq	−0.102	−0.0262	−0.0103	−0.126	−0.0202	−0.00611	−0.112	0.00249	0.0392
Obs	4,830	4,832	4,832	2,925	4,832	4,818	2,632	4,782	232

W is the state level monthly logged average hourly real wage. The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) clustered at the state level. *,**, and *** refer to significance at 10%, 5% and 1% levels.

Table 7. Impact of child flu vaccination rate on state-level hourly real wage of women in 16–24 and 25–44 years age groups by parental status, 2010–2019.

Panel A: Women Age 16–24									
	All	At Least One Child	At Least One Child < 5	All	At Least One Child	At Least One Child < 5	All	At Least One Child	At Least One Child < 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vaccination-6M4YR $_{i(m-1)t}$	0.027***	0.045***	0.041***						
	(0.004)	(0.010)	(0.009)						
Vaccination-512 $_{i(m-1)t}$				0.026***	0.037***	0.035***			
				(0.003)	(0.008)	(0.008)			
Vaccination-1317 $_{i(m-1)t}$							0.018***	0.032***	0.031***
							(0.002)	(0.007)	(0.007)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	55.92	34.66	37.74	92.79	55.98	52.26	100.4	44.70	40.03
R-Sq	−0.639	−0.470	−0.362	−0.489	−0.266	−0.244	−0.251	−0.242	−0.224
Obs	4,891	2,964	2,668	4,899	2,964	2,667	4,719	2,862	2,576
Panel B: Women Age 25–44									
	All	At Least One Child	At Least One Child < 5	All	At Least One Child	At Least One Child < 5	All	At Least One Child	At Least One Child < 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Vaccination-6M4YR $_{i(m-1)t}$	0.017***	0.018***	0.017***						
	(0.003)	(0.004)	(0.005)						
Vaccination-512 $_{i(m-1)t}$				0.016***	0.017***	0.016***			
				(0.003)	(0.003)	(0.005)			
Vaccination-1317 $_{i(m-1)t}$							0.011***	0.011***	0.010***
							(0.002)	(0.002)	(0.003)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	53.69	51.98	52.55	95.95	95.82	97.82	109	106.9	107.8
R-Sq	−0.361	−0.242	−0.075	−0.249	−0.167	−0.049	−0.113	−0.078	−0.019
Obs	4,893	4,893	4,842	4,901	4,901	4,850	4,721	4,721	4,674

Notes: *W* is the state level monthly logged average hourly real wage. The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) clustered at the state level. *,**, and *** refer to significance at 10%, 5% and 1% levels.

vaccination are approximately the same for working mothers with at least one child (columns (2), (5), (8)), and the child is younger than 5 years old (columns (3), (6), (9)) in upper and lower panels of Table 7. Furthermore, we find that the effect of children's vaccination on women's wages for both 16–24 and 25–44 age groups decreases with children's vaccination age and is the largest for 6 months–4 years and 5–12 years old groups. The point estimates for the 13–17 years old children's vaccination status drop significantly in columns (7)–(9). For example, while the effect of a 1% increase in the vaccination rate of children aged 6 months–4 years is around 1.7% in column (3) for working women with at least one child younger than five, it drops to 1.0% for the group aged 13–17 years in column (9) of Panel B. These are indeed economically significant effects.

Based on our analytical findings (Eq. (E) in Section A2, Online Appendix A), we also expect the effect of vaccination status on wages to be heterogeneous across workers with different education levels. In particular, given that low-skilled women are less likely to have paid sick leave in their employment contracts, becoming ill (themselves or their children) will mean either quitting their jobs or losing wages; therefore, vaccination status is more likely to affect their wages. These results are consistent with some of the literature (Baum and Ruhm 2016; Rossin-Slater, Ruhm, and Waldfogel 2013). Therefore, we divide the sample based on college education status (i.e. college-educated if they have attended college or more, and non-college-educated otherwise) and report the results for working women aged 16–24 and with at least one child in Table 8(a) Part I and the same for the age group 25–44 in Table 8(b) Part II. In Panel A of both Table 8(b) Part II and 8 Part II, we focus on the effect of the adult vaccination rate on college/non-college-educated women workers with at least

Table 8a. Part I: Impact of adult flu vaccination rate on state-level hourly wage of women aged 16–24 by parental status and education level, 2010–2019.

	Mother's Age 16–24				Mother's Age 16–24			
	At Least One Child		At Least One Child < 5		At Least One Child		At Least One Child < 5	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	College	Non-College	College	Non-College	College	Non-College	College	Non-College
	Panel A: Flu Vaccination Rate 18–64 Years				Panel B: Flu Vaccination Rate 6 Months–4 Years			
Vaccination $_{i(m-1)t}$	0.026***	0.036***	0.022*	0.031***	0.028***	0.047***	0.026**	0.045**
	(0.009)	(0.010)	(0.012)	(0.011)	(0.010)	(0.015)	(0.012)	(0.017)
All Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	83.97	58.33	75.69	37.54	22.65	17.43	22.63	12.78
R-Sq	−0.038	−0.116	−0.013	−0.072	−0.096	−0.577	−0.060	−0.466
Obs	1,310	1,759	1,119	1,520	1,328	1,781	1,133	1,542
	Panel C: Flu Vaccination Rate 05–12 Years				Panel D: Flu Vaccination Rate 13–17 Years			
Vaccination $_{i(m-1)t}$	0.029**	0.040***	0.025*	0.035***	0.030**	0.033***	0.024*	0.030***
	(0.011)	(0.011)	(0.014)	(0.011)	(0.013)	(0.010)	(0.014)	(0.011)
All Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	27.28	29.11	27.26	24.58	13.54	22.12	14.13	17.04
R-Sq	−0.104	−0.344	−0.082	−0.245	−0.121	−0.321	−0.070	−0.249
Obs	1,329	1,785	1,135	1,545	1,279	1,728	1,090	1,495

Notes: The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) clustered at the state level. *,**, and *** refer to significance at 10%, 5% and 1% levels.

Table 8b. Part II: Impact of adult flu vaccination rate on state-level hourly wage of women aged 25–44 by parental status and education level, 2010–2019.

	Mother's Age 25–44				Mother's Age 25–44			
	At Least One Child		At Least One Child < 5		At Least One Child		At Least One Child < 5	
	(1) College	(2) Non-College	(3) College	(4) Non-College	(5) College	(6) Non-College	(7) College	(8) Non-College
	Panel A: Flu Vaccination Rate 18–64 Years				Panel B: Flu Vaccination Rate 6 Months–4 Years			
Vaccination $_{i(m-1)t}$	0.017***	0.019***	0.015***	0.022***	0.020***	0.023***	0.019***	0.027***
	(0.003)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)
All Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	159.8	155.9	167.2	137.1	50.49	58.20	49.16	63.59
R-Sq	−0.031	−0.079	−0.007	−0.025	−0.202	−0.329	−0.069	−0.178
Obs	4,829	4,756	4,633	3,551	4,889	4,817	4,692	3,593
	Panel C: Flu Vaccination Rate 05–12 Years				Panel D: Flu Vaccination Rate 13–17 Years			
Vaccination $_{i(m-1)t}$	0.019***	0.021***	0.018***	0.026***	0.012***	0.014***	0.011***	0.019***
	(0.003)	(0.003)	(0.005)	(0.005)	(0.002)	(0.002)	(0.003)	(0.004)
All Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State and Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
KP LM p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KP Wald F-stat	94.24	97.99	92.61	83.81	103.4	105.6	103.4	86.87
R-Sq	−0.147	−0.237	−0.052	−0.112	−0.072	−0.140	−0.023	−0.081
Obs	4,897	4,826	4,698	3,604	4,717	4,649	4,526	3,474

Notes: The subscripts *i* denote state, *m* represents month, and *t* indicates year. IV regressions with robust standard errors (in parentheses) clustered at the state level. *,**, and *** refer to significance at 10%, 5% and 1% levels.

one child. Panels B, C, and D focus on children's vaccination rate in three age groups: 6 months–4 years, 5–12 years, and 13–17 years. Panel A shows a significant and positive effect of adult vaccination on the wages of both groups of women with at least one child, while the effects are stronger for women with a child younger than five. In both cases, the effect is significantly stronger for non-college-educated women (columns (2) and (4) vs. (1) and (3)). As shown in Table 8(b) Part II, a 1% increase in adult vaccination rate leads to a 1.9–2.2% increase in wages of non-college-educated mothers and a 1.5–1.7% increase in wages of college-educated women.

In Panels B, C and D of both Table 8(a) Part I and 8 Part II, we focus on women with at least one child (columns (1)–(2) &; (5)–(6)) and with at least one child younger than five (columns (3)–(4) &; (7)–(8)), we find that the stronger wage effect comes from the vaccination rate of younger children aged 6 months–4 years (Panel B) and 5–12 years (Panels C), but remains significant for the older children 13–17 years (Panel D). Across the two groups of women aged 25–44 by parental status, the wage effects of children's vaccination in panels B to D are significantly greater for non-college-educated than for college-educated women. Furthermore, the wage effects of vaccination are higher for women with at least one child less than 5 years old than for women with at least one child. All regressions here include the same set of control variables, and full results, including the OLS estimates, are reported in the Online Appendix Tables C5 and C6.

IV. Conclusion

This paper examines the effects of flu vaccination on women's wages and highlights the importance of workers' age, parental status, education, and children's age. Using state-level seasonal influenza vaccination data and a 2SLS estimation method, we find that adult vaccination has significant and positive wage (and work hours) effects for working women, especially for the 16–44-year age group. Furthermore, these effects are significantly larger for mothers. In particular, parents of children aged 6 months to 12 years benefit most from their children's vaccination. Our results extend beyond adult vaccination to include children's vaccination rates.

Given the lack of a national paid family leave policy in the US, we find that children's vaccination rates are a significant determinant of parents' wages, particularly for parents of younger children. Expanding vaccination coverage across the population, including children, helps reduce illness and related work absences, especially for women who often manage family care. As a result, policies that expand vaccination coverage can significantly improve women's labour market participation and earnings. We emphasize that policies encouraging child influenza vaccination function not only as public health measures but also as meaningful economic support for working mothers.

Our findings also highlight significant differences across age and education levels. We find that younger and non-college-educated women benefit the most from their own and their children's vaccination. These results have significant policy implications and underscore the importance of public health interventions such as vaccination for labour market dynamics. Our findings also support prior work highlighting the need for a national paid sick leave and family leave programme, which offers significant economic benefits. In addition, adult flu vaccination rates in the South and West lag behind the Northeast and Midwest, suggesting a scope for targeted regional policy interventions.

Our study extends the existing literature by examining the vaccination status of adults, parents, and children as a critical yet often overlooked aspect of the health-earnings relationship. Our findings open up a crucial policy discussion on women's options for taking time off from work when their children need care, which is particularly important for women with younger children. This work-time flexibility often becomes a vital choice variable in occupational sorting and labour force participation. Our results also suggest a need to further examine the welfare implications of the stronger effects of vaccination on younger and non-college-educated women.

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Author contributions

CRediT: **Pallab Ghosh:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Firat Demir:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Myongjin Kim:** Conceptualization, Investigation, Methodology, Project administration, Validation, Visualization, Writing – review & editing; **Ahmed Chaudhry:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Junying Zhao:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing.

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References

Acemoglu, D., and S. Johnson. 2007. "Disease and Development: The Effect of Life Expectancy on Economic Growth." *Journal of Political Economy* 115 (6): 925–985. https://doi.org/10.1086/529000.

Akazawa, M., J. L. Sindelar, and A. D. Paltiel. 2003. "Economic Costs of Influenza-Related Work Absenteeism." *Value in Health* 6 (2): 107–115. https://doi.org/10.1046/j.1524-4733.2003.00209.x.

Barro, R. J., J. F. Ursúa, and J. Weng. 2020. *The Coronavirus and the Great Influenza Pandemic: Lessons from the "Spanish Flu"' for the Coronavirus's Potential Effects on Mortality and Economic Activity*. National Bureau of Economic Research.

Bartik, A., M. Bertrand, F. Lin, J. Rothstein, and M. Unrath. 2020. "Measuring the Labor Market at the Onset of the COVID-19 Crisis." *Brookings Papers on Economic Activity* 2020 (2): 239–268. https://doi.org/10.1353/eca.2020.0010.

Bartik, T. J. 1991. *Who Benefits from State and Local Economic Development Policies?* W.E. Upjohn Institute.

Baum, C. L., and C. J. Ruhm. 2016. "The Effects of Paid Family Leave in California on Labor Market Outcomes." *Journal of Policy Analysis and Management* 35 (2): 333–356. https://doi.org/10.1002/pam.21894.

BEA. 2021. "Regional Real Gross Domestic Product Chained Dollars." U.S. Bureau of Economic Analysis. Accessed September 29, 2021. https://apps.bea.gov/iTable/index_regional.cfm.

Bernstein, S., A. North, J. Schwartz, and L. M. Niccolai. 2016. "State-Level Voting Patterns and Adolescent Vaccination Coverage in the United States, 2014." *American Journal of Public Health* 106 (10): 1879–1881. https://doi.org/10.2105/AJPH.2016.303381.

Bloom, D. E., and A. S. Mahal. 1997. "Does the AIDS Epidemic Threaten Economic Growth?" *Journal of Econometrics* 77 (1): 105–124. https://doi.org/10.1016/S0304-4076(96)01808-8.

Borusyak, K., and P. Hull. 2023. "Nonrandom Exposure to Exogenous Shocks." *Econometrica* 91 (6): 2155–2185. https://doi.org/10.3982/ECTA19367.

Borusyak, K., P. Hull, and X. Jaravel. 2022. "Quasi-Experimental Shift-Share Research Designs." *Review of Economic Studies* 89 (1): 181–213. https://doi.org/10.1093/restud/rdab030.

Brodeur, A., D. Gray, A. Islam, and S. Bhuiyan. 2021. "A Literature Review of the Economics of COVID-19." *Journal of Economic Surveys* 35 (4): 1007–1044. https://doi.org/10.1111/joes.12423.

Carillo, M. F., and T. Jappelli. 2022. "Pandemics and Regional Economic Growth: Evidence from the Great Influenza in Italy." *European Review of Economic History* 26 (1): 78–106. https://doi.org/10.1093/erehj/heab009.

CDC. 2021a. "Influenza Vaccination Coverage for All Ages (6 + Months), United States, 2010-2019." Centers for Disease Control and Prevention. Accessed June 27, 2021. https://data.cdc.gov/Flu-Vaccinations/Influenza-Vaccination-Coverage-for-All-Ages-6-Mont/vh55-3he6.

CDC. 2021b. "Underlying Cause of Death 1999-2019 on CDC WONDER Online Database." United States Department of Health and Human Services (US DHHS) AND Centers for Disease Control and Prevention (CDC) AND National Center for Health Statistics (NCHS). Accessed November 8, 2021. https://wonder.cdc.gov/.

CDC, and FDA. 2022. *Vaccine Adverse Event Reporting System*. Centers for Disease Control and Prevention, and U.S. Food and Drug Administration. Accessed March 8, 2022. https://vaers.hhs.gov/data.html.

Choudhury, A. R., and S. W. Polachek. 2021. "The Impact of Paid Family Leave on the Timely Vaccination of Infants."

Vaccine 39 (21): 2886–2893. https://doi.org/10.1016/j.vaccine.2021.03.087.

Egede, L. E., and D. Zheng. 2003. "Racial/Ethnic Differences in Influenza Vaccination Coverage in High-Risk Adults." *American Journal of Public Health* 93 (12): 2074–2078. https://doi.org/10.2105/AJPH.93.12.2074.

Flood, S., M. King, R. Rodgers, S. Ruggles, and J. R. Warren. 2021. *Integrated Public Use Microdata Series, Current Population Survey: Version 9.0 Current Population Surveys (CPS)*. Minneapolis: IPUMS. https://doi.org/10.18128/D030.V9.0 .

Gupta, S., L. Montenovo, T. Nguyen, F. Lozano-Rojas, I. Schmutte, K. Simon, B. A. Weinberg, and C. Wing. 2023. "Effects of Social Distancing Policy on Labor Market Outcomes." *Contemporary Economic Policy* 41 (1): 166–193. https://doi.org/10.1111/coep.12582.

Jensen, S., and J. McIntosh. 2007. "Absenteeism in the Workplace: Results from Danish Sample Survey Data." *Empirical Economics* 32 (1): 125–139. https://doi.org/10.1007/s00181-006-0075-4.

KFF. 2017. *Employer Health Benefits Survey*. CA: Henry J. Kaiser Family Foundation Menlo Park.

KFF. 2019. *2019 Employer Health Benefits Survey*. CA: Henry J. Kaiser Family Foundation Menlo Park.

KFF. 2021. *Paid Leave in the U.S.* CA: Henry J. Kaiser Family Foundation Menlo Park.

Kleibergen, F., and R. Paap. 2006. "Generalized Reduced Rank Tests Using the Singular Value Decomposition." *Journal of Econometrics* 133 (1): 97–126. https://doi.org/10.1016/j.jeconom.2005.02.011.

Lee, P. Y., D. B. Matchar, D. A. Clements, J. Huber, J. D. Hamilton, and E. D. Peterson. 2002. "Economic Analysis of Influenza Vaccination and Antiviral Treatment for Healthy Working Adults." *Annals of Internal Medicine* 137 (4): 225–231. https://doi.org/10.7326/0003-4819-137-4-200208200-00005.

Løkke, N. A.-K. 2008. "Determinants of Absenteeism in Public Organizations: A Unit-Level Analysis of Work Absence in a Large Danish Municipality." *International Journal of Human Resource Management* 19 (7): 1330–1348. https://doi.org/10.1080/09585190802110158.

Masia, N. A., J. Smerling, T. Kapfidze, R. Manning, and M. Showalter. 2018. "Vaccination and GDP Growth Rates: Exploring the Links in a Conditional Convergence Framework." *World Development* 103:88–99. https://doi.org/10.1016/j.worlddev.2017.10.013.

Mathieu, E., H. Ritchie, L. Rodés-Guirao, C. Appel, D. Gavrilov, C. Giattino, and M. Roser. 2020. "COVID-19 Pandemic." *Our World in Data*. https://ourworldindata.org/coronavirus .

Medina-Garrido, J. A., J. M. Biedma-Ferrer, and J. Sánchez-Ortiz. 2020. "I Can't Go to Work Tomorrow! Work-Family Policies, Well-Being and Absenteeism." *Sustainability* 12 (14): 5519. https://doi.org/10.3390/su12145519.

Mincer, J. 1958. "Investment in Human Capital and Personal Income Distribution." *Journal of Political Economy* 66 (4): 281–302. https://doi.org/10.1086/258055.

Molinari, N.-A. M., I. R. Ortega-Sanchez, M. L. Messonnier, W. W. Thompson, P. M. Wortley, E. Weintraub, and C. B. Bridges. 2007. "The Annual Impact of Seasonal Influenza in the US: Measuring Disease Burden and Costs." *Vaccine* 25 (27): 5086–5096. https://doi.org/10.1016/j.vaccine.2007.03.046.

Montenovo, L., X. Jiang, F. L. Rojas, I. M. Schmutte, K. I. Simon, B. A. Weinberg, and C. Wing. 2022. "Determinants of Disparities in Early COVID-19 Job Losses." *Demography* 59 (3): 827–855. https://doi.org/10.1215/00703370-9961471.

Nichol, K. L. 2001. "Cost-Benefit Analysis of a Strategy to Vaccinate Healthy Working Adults Against Influenza." *Archives of Internal Medicine* 161 (5): 749–759. https://doi.org/10.1001/archinte.161.5.749.

OECD. 2020. *Paid Sick Leave to Protect Income, Health and Jobs Through the COVID-19 Crisis* OECD Policy Responses to Coronavirus (COVID-19) (Paris: OECD Publishing). https://doi.org/10.1787/a9e1a154-en

Piper, K., A. Youk, A. E. James III, and S. Kumar. 2017. "Paid Sick Days and Stay-at-Home Behavior for Influenza." *PLOS ONE* 12 (2): e0170698. https://doi.org/10.1371/journal.pone.0170698.

Quilici, S., R. Smith, and C. Signorelli. 2015. "Role of Vaccination in Economic Growth." *Journal of Market Access & Health Policy* 3 (1): 27044. https://doi.org/10.3402/jmahp.v3.27044.

Rossin-Slater, M. 2017. "Maternity and Family Leave Policy (Working Paper No. 23069)."

Rossin-Slater, M., C. J. Ruhm, and J. Waldfogel. 2013. "The Effects of California's Paid Family Leave Program on Mothers' Leave-Taking and Subsequent Labor Market Outcomes." *Journal of Policy Analysis and Management* 32 (2): 224–245. https://doi.org/10.1002/pam.21676.

Rothman, T. 2017. "The Cost of Influenza Disease Burden in U.S. Population." *International Journal of Economics & Management Sciences* 6 (4): 443. https://doi.org/10.4172/2162-6359.1000443.

Times, N. Y. 2022. "COVID-19 Doses Interactive." *New York Times*. Accessed October 20. https://www.nytimes.com/interactive/2020/us/covid-19-vaccine-doses.html.

Veenstra, C. M., S. E. Regenbogen, S. T. Hawley, P. Abrahamse, M. Banerjee, and A. M. Morris. 2015. "Association of Paid Sick Leave with Job Retention and Financial Burden Among Working Patients with Colorectal Cancer." *Jama* 314 (24): 2688–2690. https://doi.org/10.1001/jama.2015.12383.

Ward, C. 2014. "Influenza Vaccination Campaigns: Is an Ounce of Prevention Worth a Pound of Cure?" *American Economic Journal: Applied Economics* 6 (1): 38–72. https://doi.org/10.1257/app.6.1.38.

White, C. 2021. "Measuring Social and Externality Benefits of Influenza Vaccination." *Journal of Human Resources* 56 (3): 749–785. https://doi.org/10.3368/jhr.56.3.1118-9893R2.

WHO. 2021. *WHO COVID-19 Dashboard*. World Health Organization. https://covid19.who.int/.

Zhang, W., H. Sun, S. Woodcock, and A. H. Anis. 2017. "Valuing Productivity Loss Due to Absenteeism: Firm-Level Evidence from a Canadian Linked Employer-Employee Survey." *Health Economics Review* 7 (1): 1–14. https://doi.org/10.1186/s13561-016-0138-y.