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Abstract

This paper investigates how high-speed home Internet has impacted labor supply. Using an instrumental variables strategy that exploits cross-state variation in supply-side constraints to residential broadband Internet access, I find that exogenously determined high-speed Internet usage leads to a 4.1 percentage point increase in labor force participation for married women. There is no corresponding effect on single women or men. Among married women, the largest increases in participation are found among college-educated women with children. Supplemental analyses suggest that Internet use for telework and time saving in home production explain the increase in participation. The results suggest home Internet facilitates work-family balance.

JEL Codes: J16, J22, O33, J13
Keywords: female labor force participation, high-speed Internet, opting out, work and family

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1 Introduction

From shopping to telecommuting, the Internet has altered how, when, and where individuals conduct a remarkable array of activities. Residential high-speed Internet subscriptions have grown at a pace that reflects the Internet's widespread usefulness: between 2000 and 2009 usage rates rose from 5 percent to 74 percent, a change that few technologies in recent history can match for speed and depth of diffusion.[1] Yet, scant evidence has been brought to bear upon the question of whether or not this technology has altered individual labor market outcomes.[2] This omission is particularly striking given economists have recognized the potential for the Internet to change labor markets for some time (e.g., Autor, 2001). This paper provides new evidence on the impact of Internet technology in the labor market and finds that home, high-speed Internet has increased married women's labor force participation.

The potential effects of Internet usage on labor supply are multidimensional because of the many different ways the Internet is used. Home Internet can reduce the time and monetary costs of working by allowing individuals to work from home, reduce search frictions in the labor market by connecting potential employees to employers, and save users time in home production tasks like shopping and paying bills, freeing up time to engage in market work. But the Internet also offers users a wide range of new entertainment options, which could increase the value of time spent in leisure and mitigate any positive effects. The net effect of home Internet use on labor supply depends on the extent to which individuals use Internet for each of these activities and the responsiveness of individual labor supply along each margin.

One reason for the scarcity of empirical work on Internet usage is the inherent difficulty in establishing a causal relationship between Internet usage and individual outcomes: Internet

[1] Usage rates were calculated from Current Population Survey data. Faulhaber (2002, figure 10-1) compares broadband diffusion to VCR and wireless phone diffusion. Greenwood et al. (2005, figure 1) displays trends in appliance diffusion. Of the technologies examined by those authors, only microwave ovens diffused at close to a similar pace (3 percent to 60 percent from 1975 to 1986).

[2] The exception is the more focused literature on Internet job search (e.g., Kuhn and Skuterad, 2004; Stevenson, 2009; Kroft and Pope, 2010; Kuhn and Mansour, 2011; Brencic, 2012).

users are not randomly assigned and take-up is likely to be endogenous to labor market outcomes. To overcome this potential bias, I propose an instrumental variables (IV) strategy that exploits cross-state variation in supply-side constraints to high-speed Internet access. Unlike dial-up Internet, high-speed Internet installation required substantial investments by Internet service providers and access was neither immediate nor uniformly distributed across locations. From an Internet service provider's perspective, multiple family dwellings were easier and more profitable for installation. Motivated by this differential investment incentive, I show that geographic variation in the housing infrastructure – namely, the percent of the state population residing in a multiple family dwellings – can predict trends in Internet usage. Conditional on state and year fixed effects, and a host of time-variant state-level labor and housing market indicators, the identification assumption is that the fraction of a state residing in multiple family dwellings would not have been correlated with subsequent trends in labor supply in the absence of broadband Internet diffusion. A placebo test indicates that the instrument cannot predict trends in labor supply prior to the diffusion of high-speed Internet.

To estimate the effect of Internet usage and labor supply, I employ micro-level Current Population Survey (CPS) data on self-reported home high-speed Internet usage and labor market outcomes. Using the proposed IV strategy, I find high-speed Internet usage leads to a 4.1 percentage point increase in married women's labor force participation. There is no effect on men or single women. Among married women, the largest increases in participation are found among college-educated women with children. Moreover, high-speed Internet also increases hours and employment rates among married women. Finally, data on Internet usage, telework, employment histories, and time use provide suggestive evidence that telework and time saved in home production can explain the estimated change in labor supply for married women.

The results indicate that high-speed Internet has the largest positive impact on the labor supply decisions of college-educated women with children, which reconciles well with aggregate trends in labor supply over the period studied. Figure 1(a) displays trends in labor force participation for men and women, separately by marital status, and figure 1(b) plots trends for married women only, separately by education and the presence of children. After almost a century of secular increases in married women's labor supply, growth stalled in the mid-1990s, and among married women with a college education, participation rates began to decline. This decline garnered media attention and popularized the term "opting out" – a hypothesis that highly educated women were choosing motherhood over their careers (Belkin, 2003; Wallis, 2004; Story, 2005).[3] Figure 1(b) illuminates another noteworthy trend: starting in the early 2000s, labor force participation rates began to rise among highly educated women with children, while rates remained on trend for other groups of married women, single women and men. The results of this paper suggest that high-speed Internet usage can at least partially explain this differential increase.[4]

The main scholarly contribution of this paper is to provide an empirical examination of how high-speed home Internet technology has affected labor market participation. This paper also adds to a more focused literature that has considered the use of Internet technology as a job search tool (Kuhn and Skuterad, 2004; Stevenson, 2009; Kuhn and Mansour, 2011; Kroft and Pope, 2010; Brencic, 2012). This work also contributes to the development of a broad understanding of how technological progress in the home affects economic outcomes. Similar to work by Greenwood, Sheshadri, and Yorukoglu (2005), who study the diffusion of washing machines, microwaves, and other home technologies, I find a substantial impact of a home-based technology on female labor force participation. I find suggestive evidence that high-speed Internet is important for the labor supply decisions of highly educated women with families because Internet facilitates work-family balance. The conflicting demands of work and family are often thought to be responsible for the persistence of the gender

[3]Empirical evidence on the topic has been mixed (Boushey, 2005; Herr and Wolfram, 2009; Macunovich, 2010). As evidenced in figure 1, the decline in labor force participation in the mid-1990s was not limited to college-educated women with children, but also applied to less educated married women with children, college educated married women without children, single women, and men.

[4]Note that this group's employment rates (conditional on participation) fell during the 2007-2009 recession, as they did for most other demographic groups.

wage gap and the relative lack of women in leadership roles (e.g., Bertrand and Hallock, 2001; Sasser, 2005; Black, Haviland, Sanders, and Taylor, 2008; Bertrand, Goldin, and Katz, 2009). This paper contributes to an empirical literature that has shown that family-friendly workplace policies can improve the labor market outcomes of women with families (Ruhm, 2004; Baker and Milligan, 2008; Herr and Wolfram, 2009). Furthermore, this paper speaks to the potential for telework and flexible scheduling policy to encourage labor market entry among skilled workers.

2 Conceptual Framework and Related Literature

There is a large literature in neoclassical economics that attempts to understand the determinants of individual labor supply decisions. In the simplest static, consumer choice framework an individual faces a tradeoff between consumption and leisure, and allocates time between the home and the market to maximize current period welfare. Becker (1965) introduced the notion that time spent at home is not only spent in leisure, but is also used productively to produce commodities like meals or clean laundry. Commodities are produced using various combinations of time and market-purchased inputs, and individuals face a tradeoff not only between consumption of different commodities, but also between using time or purchased inputs in production. Thus, one might face a choice between watching television and cleaning thehouse, as well as between ordering takeout and preparing a meal from scratch. Labor supply decisions depend upon a comparison between the value of time spent engaged in market work (the wage) and the value of time spent at home (the reservation wage), where the reservation wage is a function of preferences over commodities and the substitutability of time and inputs in production.

Home Internet is used for a wide range of activities, many of which could plausibly affect the wage or reservation wage. One broad class of activities for which Internet is used is in leisure and home production. In this case, home Internet represents a technological advance in inputs to production. For home produced goods like shopping or paying bills, a technological improvement will tend to reduce the time agents need to spend on those tasks, reducing the reservation wage and increasing participation for those who are on the margin. This change arises because the elasticity of substitution between time and inputs in production is relatively high for home production goods, so individuals will tend to substitute the new technology for their own time (Aguiar and Hurst, 2007). For leisure goods, the elasticity of substitution between time and inputs tends to be smaller, and it is more difficult to substitute technology for time to produce identical goods. If Internet technology enhances leisure activities so that they are more enjoyable than their offline counterparts, individuals will want to substitute towards time spent in leisure, leading to an increase in the reservation wage and a decline in participation for those who are on the margin.

Home Internet may also alter labor supply decisions by allowing individuals to engage in telework (conducting some or all market work remotely).[5] Telework can increase the wage by reducing commute times (and, hence, lost wages). Telework might also increase wages by enhancing productivity through reductions in absenteeism and workplace distractions, and recent work by Bloom et al. (2012) provides experimental evidence that telework can improve worker productivity. Telework opportunities could also alter the reservation wage by reducing pecuniary and non-pecuniary costs to working, such as child care expenses or psychic costs of being away from children while at work.

The most well-studied interaction between the Internet and labor markets is Internet job search, although empirical evidence has been somewhat mixed on the effectiveness of the Internet as a job search tool. Kuhn and Skuterad (2004) study the effect of Internet search on unemployment durations using data from the CPS and find that Internet search increases

[5] The propensity to telework increased substantially over the time period studied: between 2002 and 2008 overall telework increased 63 percent and employer-provided telework increased 123 percent (WorldatWork, 2006, 2009). To the best of my knowledge, there is no evidence on whether or not a causal relationship exists between the diffusion of residential broadband and telework adoption. A relationship does seem plausible, since high-speed Internet was adopted by most businesses by the mid-1990s and would have already become an important fixture of the workplace by the early 2000s. Thus, its availability at home had the potential to be a necessary component to a successful telework arrangement.

unemployment durations. Subsequent work, however, has tended to find the opposite result (Stevenson, 2009; Kuhn and Mansour, 2011) or no relationship (Kroft and Pope, 2010). These studies have all focused on unemployment durations as the outcome, but Internet search could also theoretically affect participation decisions by allowing individuals to observe higher wage or better matched jobs, effectively raising the market wage. Atasoy (2013) studies the aggregate employment effects of broadband deployment in the United States and finds increases in employment rates. The author finds this increase is attributable to both shifts from unemployment to employment, as well as increased participation.

The variety of uses of Internet technology leads to an ambiguous prediction for the overall net effect of Internet usage on labor supply, which depends upon (1) the extent to which individuals use Internet for work, job search, home production, and leisure and (2) the responsiveness of individual labor supply along each margin. Ultimately, the size and magnitude of the net effect of Internet usage on labor supply will be an empirical question. However, in conjunction with several stylized facts, it is possible to speculate about the *relative* impact of home Internet use across different groups. First, female labor supply has historically been more elastic than male labor supply (especially on the extensive margin), suggesting women should exhibit a greater response to new technology than men (e.g., Heckman, 1993). Second, telework is much more common among more educated individuals. Thus, enhanced telework opportunities should have a relatively larger impact on more educated men and women.[6] Third, research has shown that commute time negatively impacts the participation decisions of married women, which suggests a relatively larger impact of telework opportunities for this group (Black et al., 2008). Fourth, telework could reduce the costs of paid child care, which would imply that women with children – whose labor supply is known to be sensitive to the price of child care – that can engage in telework will be particularly affected (Anderson and Levine, 2000; Gelbach, 2002; Cortes and Tessada, 2008). Finally, it is a well established fact that within married couples, the majority of home production tasks and child rearing is

[6]In 2009, 65 percent of teleworkers held a college or post-graduate degree (WorldatWork, 2009).

done by women, even conditional on both partners' employment (e.g., Bianchi et al., 2000). This imbalance suggests that the ability to save time in home production tasks should have a relatively larger impact on married women than men, and especially women with children. Combining these facts suggests that the Internet should have the largest effect on married women, and particularly those with higher levels of education and children.

3 Empirical Framework

3.1 Data

The primary data source for this paper is the Current Population Survey (CPS), which isa monthly survey that collects information on labor market outcomes and demographic characteristics of its participants. In addition to the main labor force and demographic information, the CPS collects additional supplemental information on its participants that varies from month to month. The surveys I employ are the months in which information on Internet usage was collected: the August 2000 and September 2001 Computer and Internet Use Supplement, and the October 2003, 2007, and 2009 School Enrollment supplements.[7] The CPS is uniquely suited for this study because it contains extensive information on individual's current labor supply, demographic characteristics, and current Internet usage for the period of time in which high-speed Internet diffused. Table 1 summarizes the CPS data.

[7]Information on Internet usage was also collected in the 1997 and 1998 Internet Supplements. I do not use those years because it is not possible to separately identify high-speed from dial-up Internet users in those years. See the appendix for more information on Internet usage in the CPS.

3.2 Background on Broadband Internet Diffusion

High-speed, or broadband, Internet became available to residential consumers in the late 1990s and early 2000s.[8] To provide this service, Internet service providers (ISPs) had to make substantial infrastructure investments, retrofitting existing phone and cable lines and installing new switches and servers (Faulhaber, 2002; Greenstein and Prince, 2007; Grubesic and Murray, 2002). There is a general consensus that these costs slowed rollout and access did not keep up with consumer demand (Greenstein and Prince, 2007; Faulhaber, 2002).[9]

When installing residential high-speed Internet, existing wiring within a home or building generally does not need to be upgraded, but the wiring that connects the home or building's existing indoor wiring to the ISP does typically need to be upgraded. From the ISP's perspective, this made apartment buildings and other multiple-family properties easier and more profitable for installation than single-family homes. Figure 2 describes the differences between these two types of housing. For multiple-family properties – collectively referred to here as "multiple dwelling units" (MDUs) – each length of upgraded wiring installed serviced multiple customers, allowing for economies of scale and making it easier and more cost effective to provide each potential customer with access. Moreover, since the ISP or MDU owner usually held the property rights to the wiring connecting individual units within the

[8] The term "broadband" refers to "advanced communications systems capable of providing high-speed transmission of services such as data, voice, and video over the Internet and other networks" (F.C.C., 2010). Although most businesses invested in high-speed broadband Internet in the mid-1990s, the service was not offered to residential customers until the end of the decade. Transmission can be provided by a wide range of technologies, including digital subscriber lines (DSL), fiber-optic cable, coaxial cable, wireless technology, and satellite (F.C.C., 2010).

[9] Both cable-based and DSL broadband Internet service requires the installation of fiber-optic wiring, which provides high-speed Internet service up to a certain point, from which the signal travels over traditional coaxial cable or copper telephone wiring the rest of the way. These fiber-optic lines may reach the ISPs' central office, some remote terminal in the neighborhood, or the home. The main issue that prevented timely rollout for the cable companies was capacity. Cable companies had installed some fiber lines in the 1980s to provide digital cable service, but each additional customer on a single fiber line reduces the "downstream" capacity, meaning that multiple simultaneous users reduces speeds and could exhaust the system. Thus, to provide reliable, high-speed Internet service, cable companies needed to add more fiber lines thatcame closer to residences. For DSL Internet from the phone companies, rollout was prevented by the need to upgrade the existing telephone wiring, much of which was old and had been split too often to be capable of carrying high-speed two-way traffic. The key insight is that in either case, existing wiring within the home was of sufficient quality to provide individuals with access, while much of the wiring outside the home was not.

building, the ISP obtained de facto monopoly rights to service all families after installation. With these differences in mind, I propose that, all else equal, areas with more MDUs should have received Internet access *earlier* than areas with less MDUs.[10]

Information on local MDU rates was collected from the 2000 Decennial Census, which records population totals in different types of housing units based on the number of units in the structure. Based on a recent Federal Communications Commission (FCC) ruling referencing MDUs, I define an MDU as any unit in a structure with three or more units and mobile homes.[11] This definition implies that MDUs constitute about 25 percent of privately occupied residences, although there is considerable variation across states in MDU rates, which range from 14.6 percent to 47 percent. States with the greatest proportions of their population residing in an MDU include the District of Columbia, New York, Nevada, South Carolina, New Mexico, Florida, Arizona, California, North Carolina, and Georgia. States with the smallest proportions of their population in an MDU include Iowa, Pennsylvania, Nebraska, Kansas, Wisconsin, Michigan, Indiana, Ohio, Utah, and Minnesota. Appendix table 1 orders states by their 2000 MDU rate and summarizes other state-level characteristics. In the next section, I discuss the identification assumptions imposed to assume MDU rates are a valid instrument.

[10] There are also several recent working papers that have proposed identification strategies that exploit alternative supply-side constraints to access. Bhuller et al. (2011) study the impact of the Internet on sex crimes. They use cross-sectional variation in a publicly funded broadband rollout program in Norway. Falck, Gold, and Heblich (2012) study the impact of the Internet in German elections. They exploit a technological limitation of DSL provision, which creates a kink in accessibility at a precise distance from the central office of the telephone company. While this technological feature of DSL provision is also apparent in the United States, DSL has a considerably lower market share in the United States (around 30 percent, as opposed to over 95 percent in Germany). Since this kink is not present in cable-based broadband technology, it would be expected to have little predictive power for overall access rates in the United States.

[11] A recent FCC ruling defines an MDU as “a multiple dwelling unit building (such as an apartment building, condominium building or cooperative) and any other centrally managed residential real estate development (such as a gated community, mobile home park, or garden apartment); provided however, that MDU shall not include time share units, academic campuses and dormitories, military bases, hotels, rooming houses, prisons, jails, halfway houses, hospitals, nursing homes or other assisted living facilities.” (47 C.F.R. § 76.2000, 2008). Unfortunately, it is not possible to perfectly map the Census data to this definition, since it’s not clear from the Census data if a structure like a townhouse or duplex is part of a centrally managed development. Therefore, I looked at several reasonable definitions and chose the one with the most predictive power in the first stage. In the robustness checks, I estimate the model using other reasonable definitions and find similar results.

3.3 Empirical Specification

The main empirical approach used in this study is to relate individual home high-speed Internet use to labor supply for married women using ordinary least squares (OLS) and two stage least squares (2SLS). The main regressor of interest is home high-speed Internet use, which is a combination of an individual-level indicator for whether or not the individual is reported to use the Internet at home and a household level indicator for whether or not the household has a high-speed broadband Internet subscription.[12] I focus on high-speed Internet, versus dial-up, for both conceptual and empirical reasons. First, high-speed Internet is expected to be a more effective replacement for earlier technologies in the production of many of the activities that are expected to affect labor supply decisions. For example, it has been argued that both telework and shopping online were simply not feasible using slower dial-up connections (Hausman et al., 2001; Bittlingmayer and Hazlett, 2002). Second, unlike dial-up Internet, the diffusion of broadband Internet was hampered by supply-side constraints, which is essential for the identification strategy.[13]

The main labor supply outcome variable used in the analyses is an indicator for participation in the labor market. I focus on participation instead of hours in the main analyses because the economic predictions are clearer and interpretation is free of issues of self-selection into the labor market. However, in additional analyses, I will alsoestimate the effects on hours and employment status. All labor supply outcomes refer to the month of the supplement.

I relate individual high-speed Internet usage to individual labor supply using 2SLS, where the first stage is a linear probability model (LPM) of the impact of the instrument on high-speed Internet use:

$$HSI_{ist} = Z_{st}\gamma_1 + X_i\gamma_2 + S_{st}\gamma_3 + \theta_t + \eta_s + \nu_{ist} \quad (1)$$

[12] More details on identification of high-speed Internet users in the CPS data can be found in the appendix.

[13] Dial-up Internet required only that the user have a phone line and did not require any extra installation from the ISP; thus, usage was almost entirely demand driven.

HSI_{ist} is a dummy variable for whether or not individual i reports using the Internet in a household with broadband in state s and year t. The instrument, Z_{st} , is defined as $Z_{st} = MDU_s * \theta_t$, where MDU_s is the percent of the state's population that resides in a housing unit that is classified as an MDU in 2000. MDU_s is expected to affect differences across states in trends in Internet availability. Thus, MDU_s is interacted with the vector of year fixed effects θ_t to allow the identification of flexible trends in Internet diffusion across states.[14] Since I propose that places with higher MDU_s should have received Internet earlier, the impact of $MDU_s * \theta_t$ should be relatively more positive in earlier years of the sample than the later years of the sample. For that reason, $MDU * \theta_{t=2009}$ is the omitted category in all specifications, and the coefficients on $MDU * \theta_{t=2000-2007}$ are expected to be positive and become closer to zero over time. Table 2 displays the results of estimating equation (1) and indicates that the first stage exhibits the expected relationship. The main effect of MDU_s describes the conditional correlation between MDU rates and Internet usage and only varies at the state level, so it is perfectly correlated with the state fixed effects and is not included in the model. This omission is not a limitation because there is no clear prediction for the expected level relationship between MDU_s and HSI_{ist}. The instrumental variables strategy exploits variation in trends in rollout induced by cost differences across locations, not the level correlation between MDU rates and Internet usage.

The second stage equation relates high-speed Internet use to labor supply:

$$y_{ist} = \widehat{HSI}_{ist}\beta_1 + X_i\beta_2 + S_{st}\beta_3 + \theta_t + \eta_s + \epsilon_{ist} \tag{2}$$

where y_{ist} is an indicator for labor force participation for individual i in state s in year t. θ_t are year fixed effects, η_s are state fixed effects, and ϵ_{ist} is the error term. State fixed effect $\eta_s$and year fixed effects θ_t are included to ensure the estimated coefficient on HSI_{ist} is net of any time-invariant differences across states and national trends in Internet access

[14]In table 5 I display results using a more restrictive binary instrument which takes on a value of one when MDU_s is above its mean and the time period is 2000-2003 and a value of zero otherwise..

and participation. Standard errors are adjusted for clustering at the state level.

A vector of individual controls X_i is included to absorb demographic differences in rates of home Internet use and labor supply. In some specifications, I also interact some of the X_i variables with both HSI_{ist} and Z_{st} to identify separating effects for subgroups of the population.[15] A vector of time-variant state-level controls, S_{st}, is included to mitigate concerns that various aspects of the labor and housing market may be correlated with trends in home Internet usage and labor supply.[16] These controls were matched by the individual's state of residence and the year of the survey. Table 1 describes the state-level variables used in the model and their sources. Net of these demographic and economic differences across locations, leftover variation in housing stocks across states is expected to be a function of factors such as historical zoning ordinances, weather, and elevation, and the intuition behind the empirical strategy is rooted in how these longstanding differences across locations affected the timing of Internet availability.

The key identifying assumption for interpreting the results of this analysis as causal is that baseline state MDU rates would not have been systematically correlated with subsequent trends in labor supply in the absence of residential broadband Internet diffusion. This assumption does not imply that *level* MDU rates need be uncorrelated with *level* differences across states' labor supply. Indeed, states with higher MDU rates in 2000 also tended to have higher average incomes, higher average wages, greater population densities, and higher housing prices in 2000, all of which might be related to level differences in labor supply.[17] So long as these types of correlations are time-invariant, they are absorbed in the state fixed effect. Moreover, the model includes a host of individual and state-year demographic and economic variables described in table 1, including state-year unemployment rates, home

[15]In those cases, I estimate both $\widehat{HSI_{Ist} * I(X_i = x)}$ and $\widehat{HSI}_{ist}$ in two separate equations, using both $Z_{st} * I(X_I = x)$ and Z_{st} as instruments in both equations, where $I(X_i = x)$ is an indicator for membership in a subgroup of interest.

[16]Table 5 displays results of estimating the model with interactions between the 2000 level of all state-level variables and year fixed effects.

[17]Appendix table 1 rank orders states by the instrument and includes summary information on state level average wages, income, housing prices, and population density.

prices, wages, income, population density, and Internet-intensive employment rates, which control for trend differences in labor and housing markets across states. Exogeneity is satisfied if a state's 2000 MDU rate is not correlated with within-state changes in labor supply, conditional on within-state changes in measured labor and housing market conditions.

Ultimately, the exclusion restriction is untestable. Although the model controls for changes in numerous within-state characteristics, there may still be some omitted variable which is correlated with MDU rates and trending in way that affects labor force participation. One obvious example would be if MDU rates also affected trends in Internet use in the workplace, and altered trends in labor demand.[18] Fortunately for this analysis, commercial broadband Internet became available much earlier than residential broadband in the United States, and business broadband adoption was nearly universal by the time residential broadband was introduced.[19] Moreover, the identification strategy focuses on differential effects across groups. As a preview of the results, I find high-speed Internet affect married women's – but not men's or single women's – labor supply. Any correlated, unobservable labor market trends that are common to different worker types would also impact men and single women, so threats to identification are limited to unobservable correlates to MDU rates that impact married women alone.

While there is no direct way to test the exclusion restriction, I can further probe the assumption by conducting a placebo test of the reduced form impact of the instrument on labor force participation *prior* to the availability of high-speed Internet. If MDU rates are correlated with trends in labor supply at that time, there would be serious doubt that the exclusion restriction would be satisfied during the time period in which high-speed Internet

[18]Indeed, there is recent research indicating that usage of broadband Internet at work might alter labor demand (Akerman, Gaarder, and Mogstad, 2013).

[19]The analysis also includes two measures of Internet usage at work: "adoption" and "enhancement," which measure the share of the population in each year employed in industries that use the Internet for each of these purposes. These measures are constructed from the industry specific measures estimated by Forman, Goldfarb, and Greenstein (2003). Adoption refers to the percent of firms in an industry that use the Internet for any purpose, while enhancement refers to using the Internet to enhance business, such as through commercial sales online. These measures are interacted with state-year-industry level employment rates to create a measure of state-year Internet adoption and enhancement rates at work.

was available. For this placebo test, I use 1990 to 1997, since the first residential broadband subscriptions became available in 1998 (Faulhaber, 2002). The convenient feature of studying this particular time frame for the placebo test is that both business broadband subscriptions and residential dial-up Internet subscriptions were plentiful, but residential broadband was not available. The sample I use for the reduced form analysis is a sample of married women only.[20] Figure 3 displays the results the reduced form analysis graphically for the 1990 to 1997 period, where the specification is the reduced form version of equations (1) and (2) estimated on the subpopulation of married women only, and all control variables are for the 1990 to 1997 time period (including the MDU rate, which is measured in 1990). The data indicate that during this time period, there is no significant impact of an increase in state MDU rates on married women's participation for any of the years shown (relative to the year 1997) and the point estimates display no clear trend or pattern and remain close to zero. More formally, a joint test indicates that the coefficients are not jointly different from zero, indicating MDU rates are not predictive of trends in married women's labor force participation in the 1990s.[21]

A remaining threat to assigning a causal interpretation to the estimated β_1 is the possibility of sorting in response MDU rates due to expectations about future Internet access. To the best of my knowledge, the fact that MDU rates can predict trends in access was (and remains) not well known. I also chose to construct the instrument at the state level (as opposed to a more disaggregated level like county) because concerns about this type of differential sorting are mitigated by the fact that cross-state migration is relatively low. The potential drawback to employing a measure constructed at a more aggregated level is

[20]This specification is different from than the main specification used in this paper. In these estimates, the reduced form is estimated for married women only, while in the main IV specification, I estimate the model on all adults with interactions terms between Internet usage and group-level indicators. I use a different specification for ease of interpretation, as the reduced form equivalent of the main specification includes many interactions terms and is more difficult to convey graphically. Anologous 2SLS results estimated on only the subpopulation of married women are described in a web appendix to this paper, which can be found at: ADD.

[21]Conducting the same exercise in the sample period 2000 to 2009 used in the main analyses indicates the coefficients are jointly different from zero, with a p-value of 0.058 on the F-statistic.

increased measurement error in the first stage if there is substantial within-state variation in the instrument, which would only be problematic to the extent that it reduces the instrument's predictive power and creates a weak instrument problem. This scenario turns out not to be the case in this data, as first stage diagnostics indicate that the state-level instrument is sufficiently powerful and therefore, state is the preferred level of analysis.[22]

4 Estimation Results

4.1 Effects on Labor Force Participation

Table 3 displays the results of estimating equations (1) and (2). Column (1) displays the results of simple LPM estimates of equation (2), estimated using OLS. The model includes all demographic and state-level controls described in table 1. This coefficient on HSI_{ist} indicates that high-speed Internet usage is associated with a 4.3 percentage point increase in labor force participation, which is statistically significant at the one percent level. The results displayed in column (1) of table 3 do not address the possibility of endogenous selection into Internet usage, so column (2) estimates the model using the proposed IV strategy. Conceptually, it is not clear ex ante whether the naive OLS estimates will over or understate the causal effect of Internet usage. On the one hand, monthly subscription fees may be cost prohibitive for individuals who do not work, so the OLS estimates might overstate the true impact of Internet use on labor supply. On the other hand, if individuals who work spend less time in the home and place less value on a technology that is only used within the home, or if broadband at work is a substitute for broadband in the home, the OLS estimates might

[22]More disaggregated measures such as city or county are only available for CPS respondents living in sufficiently populous cities/counties. Therefore, using a more disaggregated measure would systematically remove individuals in rural areas and less populated cities from the analysis. This not only reduces the sample size but it also removes much of the variation in the timing of access since rural consumers tended to receive access later. Moreover, because I estimate the model using 2SLS, the level of geographic variation in which the instrument is defined determines the level of geography at which predicted Internet usage is constructed. Using a more disaggregated geographic unit than state to construct the instrument would lead to thin cells in which those predictions are made.

understate the true impact of home Internet use on labor supply.

The coefficient on HSI_{ist}in column (2) of table 3 indicates that high-speed Internet exerts almost no effect on labor force participation: the results are one-tenth of the size of the OLS results and statistically insignificant. This result implies the naive OLS estimate overstates the effect of Internet usage, consistent with working individuals being more able to purchase an Internet subscription. Note that the first stage F-Statistic of 10.37 is above the conventional thresholds for weak identification, indicating that the instrument is indeed powerful and relevant.[23]

The conceptual framework outlined in section 2 suggests that labor supply effects of high-speed Internet may be heterogeneous because of the many different ways Internet is used. In particular, we would expect the effects to be more relatively positive for women than men. Column (3) estimates the model with an interaction term between the indicator for high-speed Internet usage and an indicator for being a woman. The coefficient on the level term HSI_{ist} indicates there is no statistically significant effect of high-speed Internet usage for men. However, the coefficient on $HSI * Woman$ indicates that for women, high-speed Internet usage is associated with a positive and statistically significant increase in labor force participation. Relative to male Internet users, women who use high-speed Internet are 3.5 percentage points more likely to participate in the labor force.

Next, I split women according to their marital status in column (4) of table 3. The coefficient on $HSI * Woman(Married)$ indicates that relative to men, married women who use high-speed Internet are 6.5 percentage points more likely to participate in the labor force. Single female high-speed Internet users, on the other hand, are no more likely to participate

[23]First stage estimates are displayed in table 2. The F-Statistic employed is the conventional Wald F-Statistic, which is commonly used to test for weak identification. Since I have employed clustered standard errors and the Wald F-Statistic assumes i.i.d. standard errors, I have alternatively calculated a "robust" version of the F-Statistic that employs the Kleibergen and Paap (2006) rk statistic, as suggested by Baum, Schaffer, and Stillman (2007). In practice, the two are nearly identical in all specifications and using the Wald F-Statistic does not affect interpretation. The "conventional thresholds" for weak identification are the Stock-Yogo critical values. Stock and Yogo (2005) provide two methods for evaluating the presence of weak instruments: for the test based on 2SLS bias, the 10% critical value is 10.27, and for the test based on 2SLS, the 20% critical value is 10.26.

than male Internet users, and for both men and single women the effects are close to zero and statistically insignificant. Since single women appear to respond no differently than men, column (5) pools men and single women and focuses on the differential effects for married women. The results in column (5) indicate that married women who use high-speed Internet are 6.9 percentage points more likely to participate in the labor force than single women or men who use high-speed Internet. Overall, high-speed Internet is associated with a 4.1 percentage point increase in labor force participation for married women. At the mean, this represents a 5.6 percent increase in participation.[24]

Columns (6) and (7) further narrows in on the groups of interest by separating married women by their level of education and the presence of children. Column (6) shows results separately for married women with a college degree and those without a college degree. Note that some of the first stage F-Statistics are indicative of marginally weak first stage relationships, so I exercise some caution in interpreting the results of these analyses. Relative to men and single women who use high-speed Internet, college-educated married women who use high-speed Internet are 7.3 percentage points more likely to participate in the labor force. The separating effects for less-educated married women are smaller at 6.7 percentage points. This implies that high-speed Internet increases participation rates among college educated married women by 8 percent more than less educated married women. The overall impact of high-speed Internet on college-educated married women is a 5.8 percentage point increase in the probability of participating in the labor force.

Finally, column (7) separates college-educated married women into those with and with-

[24]In an earlier version of this paper, I presented results obtained from alternatively estimating the model separately for the subsample married women only. Those results are available in the web appendix to this paper, which can be found at `https://sites.google.com/dettlinglisa/research/`. I have chosen to use the pooled version as the main specification for several reasons. First, the pooled analysis allows for unobservable labor market trends that are common to different worker types to be captured in the level effect. Second, the pooled analysis permits investigation of various subgroups of interest that was not feasible in the split-sample specification because of sample size issues. Third, estimating the model on the full sample mitigates positive selection bias in the linear IV estimate that was observed in the split-sample analysis, an issue is discussed in detail in the web appendix to this paper. Ultimately, the pooled and split-sample analysis arrive at very similar estimates of the effect of Internet usage on married women's labor froce participation, although in mechanically different ways.

out children. In this case, the largest separating effects are found among college-educated married women with children, followed by childless college-educated married women, and finally less educated married women. These results imply that high-speed Internet increases participation among college-educated women with children by 20 percent more than college-educated, childless, married women and 22 percent more than less-educated married women, respectively. Overall, high-speed Internet increases participation among college-educated married women with children by 5.2 percentage points, or 6.8 percent at the mean.

As evidenced by figure 1, married women's participation rates remained essentially flat throughout the 2000s. To reconcile this flatness with the estimated 4.1 percentage point increase in participation induced by high-speed Internet, it must have been the case that in the absence of high-speed Internet, labor force participation for married women would have fallen. This does not appear to be a wholly unreasonable assumption, since figure 1 indicates that participation fell for single women, single men, and married men over this time period. If I make the strong assumption that married women's participation would have followed the same trend as single women's between 2000 and 2010, married women's participation rose 3.4 percentage points (relative to the counterfactual) over this time period, which is well within a 95 percent confidence interval of the estimated effect of high-speed Internet.[25]

4.2 Effects on Hours and Employment

Internet usage could affect labor supply on the intensive margin as well as the extensive margin, and the size and even direction of the effects are not necessarily the same. In the neoclassical labor supply model, changes in the wage have an unambiguous prediction for participation decisions, but lead to competing income and substitution effects in the hours decision. Moreover, interpretation of the effects on hours is made more difficult by self-selection into the workforce. If new labor market entrants are more likely to work part time,

[25] I estimate a simple linear time trend in single women's participation between 2000 and 2010 based on the data displayed in figure 1. I use those estimates, in combination with 2000 participation rates for married women, to predict the counter-factual rate of participation for married women in 2010.

hours of work for the average participant might decline even if hours for those who were already working increased. While it is fairly standard to use selection correction methods to overcome this problem, employing such methods in an IV strategy is difficult. I therefore choose to simply estimate the effect of Internet usage on hours conditional on working, with the caveat that any observed change in hours could be a compositional effect.

Table 4 displays the results. Column (1) displays the results for hours worked per week, indicating that for married women, Internet usage leads to an 1.25 hour increase in hours worked per week relative to men and single women, which is statistically significant at the one percent level. For men and single women, the coefficient on HSI_{ist} indicates a positive, but statistically insignificant relationship. Overall, high-speed Internet causes married women to work approximately 4 more hours per week. Column (2) estimates the effects when the outcome is an indicator for whether or not an individual reports working full time, which is defined as working 35 or more hours per week. These estimatesindicate that for married women, there is a statistically significant 3.7 percentage point increase in the probability of working full time relative to men or single women, for whom the effect is not statistically different from zero.[26] Column (3) investigates the propensity to work 50 or more hours. The coefficient on $HSI * Woman(Married)$ indicates that Internet usage increases the propensity to work 50 or more hours per week by 1.23 percentage points for married women relative to single women and men, for whom the effects are positive but not statistically different from zero. Overall, this finding indicates that high-speed Internet induces married women who work to work more hours.

Next, I focus on alternative measures of labor supply. Column (4) estimates the effects for the dependent variable employment status, which indicates that married women who use high-speed Internet are 8.7 percentage points more likely to be employed than single women or men who use high-speed Internet. For single women and men, the effects are negative, but statistically insignificant. The overall effect implies that high-speed Internet increases

[26]This outcome is recorded for some individuals who do not report exact usual hours worked, so the sample size is slightly larger than the hours sample.

married women's employment by approximately 3 percentage points, or 4 percent at the mean: a slightly smaller increase than the increase in participation found in table 3.[27]

If Internet usage facilitates job search, it may alter unemployment rates as well, either by decreasing the length of unemployment spells or inducing individuals to transition from non-participation to active job search. Column (5) estimates the effect of high-speed Internet use on unemployment and indicates that married women who use high-speed Internet are 1.8 percentage points less likely to be unemployed than single women or men who use high-speed Internet. This finding is potentially consistent with high-speed Internet differentially improving search for this group, an issue I will explore in section 5. For single women and men, the effects are positive, but statistically insignificant. Together, the results imply that the overall effect of high-speed Internet use on unemployment for married women is a 1.3 percentage point increase in unemployment, which would be consistent with a small shift from non-participation to unemployment. However, the magnitude of the unemployment effect is much smaller than the effect on participation or employment, suggesting that most of the effects found in section 4.1 are explained by transitions into employment from non-participation.

4.3 Robustness Checks

I implement a number of robustness checks on the data construction and model specification, which are displayed in Table 5. Column (1) estimates the model using an alternative specification of the state-level control variables S_t. In the main specification, S_t is a vector of state-year controls for housing and labor market conditions, while the instrument is an interaction between 2000 MDU rates and the year fixed effects (θ_t). In this specification, I replace $S_t = S_{2000} * \theta_t$, where S_{2000} is the value of each state-level variable in 2000. While this alternative specification fails to capture a lot of the actual variation within states in

[27] Atasoy (2013) finds that county-level broadband Internet access increased county-level employment rates 1.8 percentage points. Since married women represent 30 percent of the adult population, my estimates correspond to roughly a 0.9 percentage point increase in employment.

labor and housing market conditions over this period, it does parallel the specification of the instrument. Column (1) indicates that the F statistic falls slightly, but the results are virtually unchanged.

Columns (2) through (4) provide results using alternative specifications of the instrument. Column (2) presents the results using a binary instrument based on whether MDU rates are above or below the median (denoted *1[MDU]*) interacted with an indicator for whether the time period is prior to 2003 (denoted *Pre*). The results are similar with this less flexible specification. Columns (3) and (4) of table 5 test the sensitivity of the results to using an alternative definition for an MDU. As described in section 4, it is not possible to perfectly map the FCC's definition of a MDU to what is available in the Census. For the main specification, I chose the one that had the largest first stage F statistic: dwellings with three or more units. Alternatively, column (3) defines an MDU as dwellings with two or more units in the structure and column (4) defines an MDU as a dwelling with five or more units in the structure, both interacted with year fixed effects as in the main specification in equation (2).[28] In each case, the results are similar to using the original definition.

5 Interpreting the Results: Why Has High-Speed Internet Changed Labor Supply?

Next, I examine the mechanisms that can potentially explain the estimated increase in participationincluding telework, job search, home production, and leisure, as described in section 2. The observed heterogeneity in the effects of Internet usage across demographic groups hints at possible mechanisms: the largest effects are found among college-educated married women with children, and these are the women for whom telework opportunities are

[28] Census records population totals by units in structure in categories. These are the two closest categories to the original definition.

likely to be particularly important. Time saved in home production may also be relatively more important for this group. The fact that Internet has no demonstrable effect on men's or single women's labor supply is suggestive evidence that job search and leisure are less important.

To examine how Internet usage for each of these activities is related to changes in labor supply, I begin by comparing group-level labor supply responses to high-speed Internet with group-level Internet usage rates for various activities, which are available in the CPS from 2000 to 2003. To do so, I estimate group-level coefficients on HSI_{ist} (β_{1g}) using equations (1) and (2) and group-level mean rates of Internet use for each of the various tasks $\frac{1}{N_{sg}} \sum_{sg} HSI(task = t)$, where groups are defined by Census division, education, and the presence of children.[29] I construct rates of use for each activity conditional upon Internet usage overall. The goal of this analysis is to inform the extent to which Internet use for each activity contributes to the estimated effect. If there is no correlation between rates of use for a task and the predicted effects, it indicates Internet use for that purpose is not an important driver of the results, while a strong positive correlation suggests Internet use for that purpose may indeed play a role in explaining the results.

Figure 4 displays the results for work, job search, shopping/paying bills (representing home production), and playing games/fun/recreation (representing leisure).[30] Both work and home production are positively associated with increases in labor supply, while Internet use for leisure, and to a lesser extent job search are slightly negatively associated with increases in labor supply.[31] Internet use for work appears to be the best explanation for the

[29]I estimate equations (1) and (2) with four interactions terms for being a married women with our without children and with our without a college education, separately by Census division.

[30]Between 2000 and 2003, the CPS asked respondents about different activities conducted online, although the wording of the questions vary from year to year. Internet use for "work" is defined as use of Internet and email for job related tasks and use of computer to work at home. Internet use for job search was asked consistently over time. To tabulate home production activities, I focused on use of Internet for "shopping/paying bills," which includes use of Internet to shop, pay bills or engage in commercial activities, purchase products and services, and bank online. To tabulate leisure activities, I focused on entertainment-related activities, including playing games, recreation, entrainment, fun, TV, movies, and radio. .

[31]This negative relationship is even more striking when one considers that Internet use for one task is highly predictive of Internet use for other tasks (correlations between tasks range from 0.15 to 0.3) and is reassuring for the validity of the strategy as a whole.

increase in participation, as it displays the strongest positive correlation between usage and β_{1g} with a coefficient on the line of best fit of 0.31. Internet use for home production also displays positive correlation with β_{1g}, although it is less strong at 0.21. In what follows, I further explore each mechanism separately.

5.1 Telework

Telework increased substantially between 2000 and 2009: the propensity for a worker to telework increased from 16 percent to 25 percent between 2002 and 2008 (WorldatWork, 2006, 2009). To understand whether telework can explain some of the labor supply results, table 6 summarizes data from the 2001 and 2004 CPS work schedules supplements, which include detailed information on telework usage. I find that 23.9 percent of married women and 44.2 percent of college-educated married women with children report engaging in telework. Rates for single women and men are lower, at 16.4 and 19.5 percent, respectively. However, among those who telework, there are not large differences in the intensity of usage in terms of days or hours per week. When asked the reason for engaging in telework, 8.5 percent of college-educated married women with children report working from home to "coordinate schedules with family or personal needs," which is more than twice the fraction of men or single women who report this reason. This finding provides direct evidence that working from home is a tool women use to balance the demands of work and family.

To determine if high-speed Internet can facilitate telework, I look across occupations in CPS Internet data and the CPS Work Schedule data to examine whether there is a correlation between occupation-specific work at home rates and occupation-specific Internet usage rates among married women who work.[32] Figure 5 displays the results, indicating there is a strong,

[32] A more precise exercise would be to examine differential effects of high-speed Internet usage on labor force participation by occupation telework-usage rates using the same regression framework used throughout this paper. Unfortunately, occupation information is only available in the data for individuals who have worked in the past year, which implies that the mean labor force participation rate among individuals with occupation information is 98.9 percent. Because of the limited number of non-participants, the results of that exercise are not reported here. However, they are suggestive of positive, differential effects of high-

positive relationship: the coefficient on a line of best fit is 0.54, and occupations in the top quartile of the distribution of mean Internet usage rates have work-at-home rates that are five times higher than those in the bottom quartile.[33]

Finally, I look at rates of self-employment and full-time telework. Full-time telework can be found in the American Communities Survey (ACS), which directly identifies exclusive telework in responses to a question on "means of transportation to work." I use this data in combination with the CPS data on Internet usage using a two-sample instrumental variables strategy (Angrist and Krueger, 1992). Self-employment is found in the CPS and can be estimated using the IV strategy used in the main analyses. Table 7 columns (1) and (2) display the results, indicating that high-speed Internet decreases the likelihood a married woman will work from home full time, and there is no statistically significant relationship between high-speed Internet and self-employment. While perhaps surprising, these results are consistent with aggregate telework trends: between 2006 and 2008, full-time telework rates fell and self-employed telework rates remained flat, while employer-provided "occasional" telework (at least one day per month) increased 114 percent (WorldatWork, 2006, 2009). These results suggests that home Internet has increased labor supply by allowing married women to engage in flexible scheduling via employers that permit occasional telework.

5.2 Job Search

There is a growing empirical literature on the role of Internet search in affecting unemployment durations, but to the best of my knowledge, there is no evidence on the role of search in affecting participation decisions and no evidence on whether or not Internet search may have had a differential impact on married women. To estimate the role of search in this

speed Internet usage for individuals in occupations with a high telework-usage rates relative to individuals in occupations with low telework-usage rates, though the effects are imprecisely estimated.

[33] The CPS work schedule data is available in 2001 and 2004, while the CPS Internet data is available in 2000, 2001, 2003, 2007, and 2009. I construct averages using all available data for each occupation. Since occupation classifications changed dramatically between the 2000/2001 supplements and 2003 to 2009 supplements, I use the BLS CPS extracts to harmonize occupations over time (See NBER, 2004) .

outcome, I exploit the longitudinal nature of the CPS sampling frame to look at the post-survey labor market outcomes of respondents who were asked whether or not they used the Internet for job search in the initial survey. I construct employment histories for the sample of married women who use the Internet at home and do not participate in the labor force and compare the transitions from non-participation to participation for home Internet users who use Internet for search to Internet users who do not use the Internet for search.[34]

I estimate two models. First, I estimate a linear probability model of the propensity for an individual to be a labor force participant one year after the initial survey. Second, I examine participation hazards using a duration model.[35] Since the sample is limited to individuals with Internet at home, I cannot use the instrumental variables strategy used earlier and I exercise caution in interpreting the results as causal since take-up of Internet search could itself be endogenously determined among Internet users. To control for the intensity of job search among those who are not participating, I include as a control variable an indicator for whether or not the individual was "doing something to look for work in the past 4 weeks" in addition to the individual-control variables used in the main analyses. Columns (3) and (4) of table 7 display the results of these exercises. The coefficient on $InternetJobSearch$ indicates that Internet use for job search is associated with an increased propensity to be in the labor force in one year and an increased participation hazard (e.g., shorter durations of non-participation). However, the coefficient on $InternetJobSearch * Woman(Married)$ indicates there is no differential effect of Internet search for married women. These results suggest that while Internet search may facilitate entry into the labor market, it seems unlikely to be responsible for the demonstrated differential increase in participation among married women.

[34] This includes the CPS supplements from 1998, 2000, 2001, and 2003. I no longer focus on only high-speed Internet, so I am able to use the 1998 supplement which does not separately identify high-speed and dial up users, but does record activities conducted online.

[35] I use the same duration model used by Kuhn and Skuterad (2004) in their analysis on unemployment durations in the CPS. The authors use a discrete-time hazard model with a fully flexible form for the baseline hazard function that accounts for the fact that the there are both left and right censored spells and eight month gaps in the data while respondents are out of the CPS sample. Stata code for their paper, which was used for this analysis, can be found at `www.econ.ucsb.edu/~pjkuhn/Data/DataIndex.html`.

5.3 Time Spent in Home Production and Leisure

Conceptually, home production and leisure can change participation decisions by changing the amount of time individuals spend on those activities, therefore freeing up or limiting the amount of time available for work. To examine differences in time spent in home production and leisure among high-speed Internet users and non-users, I use data from the American Time Use Survey (ATUS). The ATUS records time diaries of its respondents for 24-hour periods and is administered to CPS respondents, which allows me to link information about high-speed Internet usage to the data.[36] Table 8 displays the data for working adults, where the top row displays differences between high-speed Internet users and non-users in time spent in each activity, and the bottom row describes mean hours per week spent in each activity. I find that married women who are home Internet users spend 1.78 fewer hours per week in home production than non-users, and college-educated married women with children who are Interent users spend 2.81 fewer hours in home production than non-users. This contrasts starkly with male Internet users, who spend 0.45 more hours per week in home production than non-users. There is almost no difference in leisure time among married female Internet users and non-users. These results, while only correlations, suggest that home Internet usage can differentially reduce time spent in home production for married women, and especially college-educated married women with children.

[36]ATUS data can be downloaded from ATUS-X, which also provides the procedure for linking CPS and ATUS respondents. `www.atusdata.org/index.shtml` . The ATUS is a time-use survey which asks individual to record the number of minutes spent in various activities in a 24-hour period. I convert minutes per day into hours per week. Since there can be a a large time lag between when the CPS supplement was administered and when the ATUS is administered, I limit the sample to only those individuals who respond to the ATUS within 6 months of the CPS supplement.

6 Conclusion

High-speed Internet has changed the way individuals live and work. Using an instrumental variables strategy that exploits supply-side constraints to high-speed Internet access, I find evidence that exogenously determined home high-speed Internet usage leads to 4.1 percentage point increase in labor force participation for married women. There is no effect of high-speed Internet usage for single women's or men's labor force participation. Among married women, increases in labor force participation are largest for college-educated married women with children. High-speed Internet usage is also associated with increases in hours worked and employment for married women.

This work speaks to the potential labor market impact of extending high-speed Internet access, and importantly, for whom access is important. More broadly, this paper addresses the labor market effects of the diffusion of a home technology. Unlike technology diffusion in the workplace, which may directly affect productivity, the link between home technologies and labor market outcomes is less clear. Similar to work on the diffusion of time-saving appliances in the twentieth century, I find that female labor supply is sensitive to technological progress in the home sector.

The conflicting demands of work and family force households to make difficult decisions. I find suggestive evidence that telework is a leading explanation for the positive labor supply response to Internet usage, which speaks to broader policy discussions about the potential benefits of telework and flexible scheduling policies. While it is generally accepted that flexibility in the workplace has the potential to benefit employers, employees, and the economy as a whole, adoption is still low and there is little empirical evidence on the benefits/costs of these policies.[37] This paper has demonstrated that Internet usage, via take-up of telework opportunities, has allowed a group of highly educated women to join the workforce, suggesting such policies may have the potential to encourage workforce entry by productive

[37] See, for example, the report by the Council of Economic Advisers on Work-life Balance, March 2010.

individuals.

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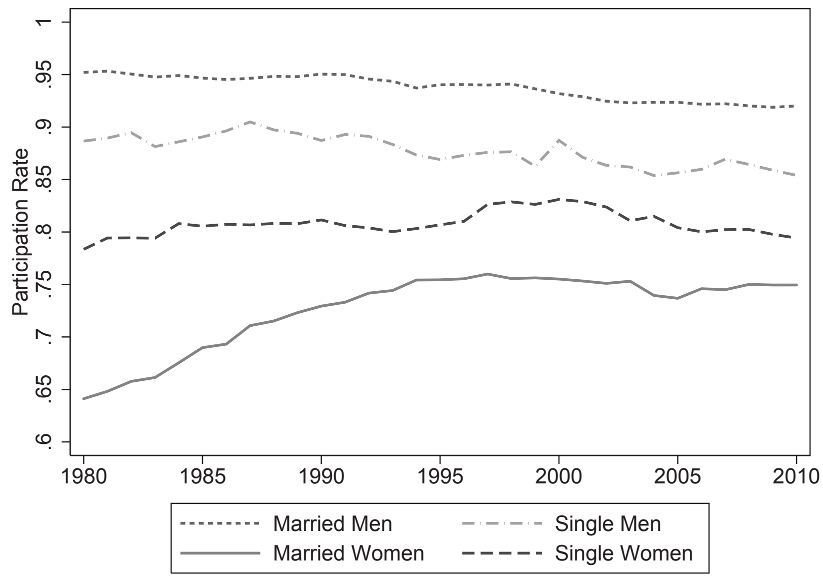
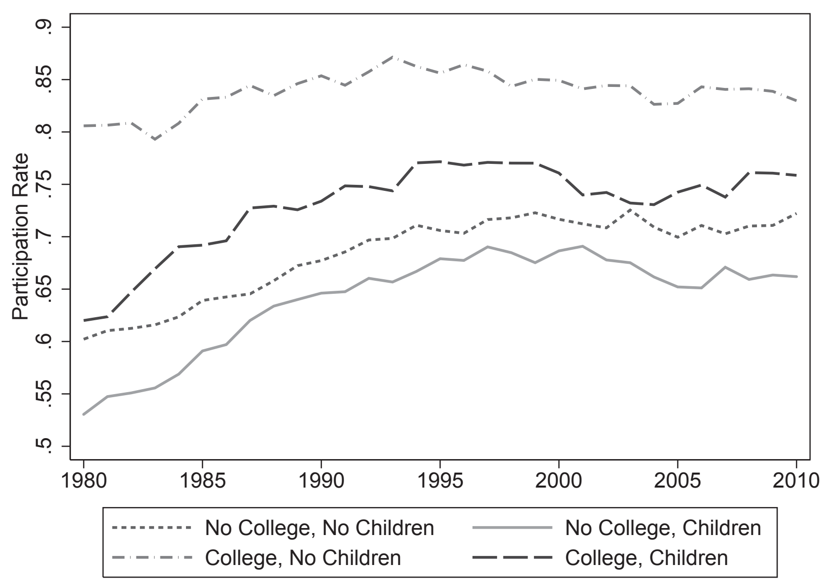
Figure 1: Trends in Labor Supply 1980 to 2010

(a) All Men and Women



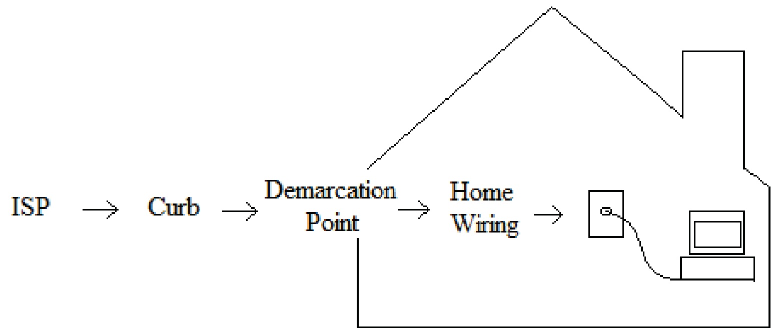
(b) Married Women



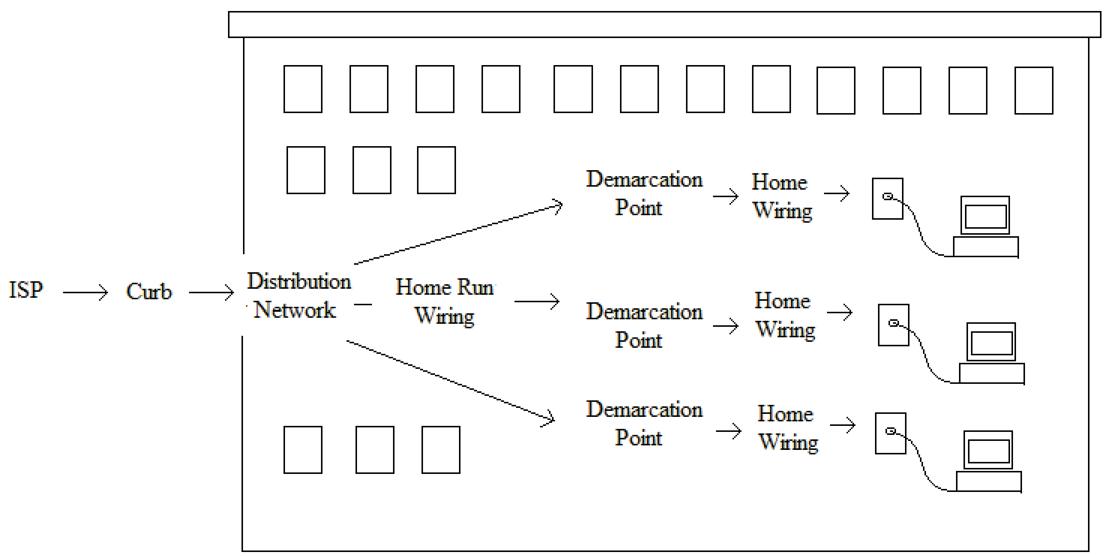
Notes: Displayed are trends in labor force participation rates for adults 18 to 59. In panel (b) the sample is further limited to married women 18-59, All trends were calculated annually from 1980 to 2010 from the Annual Social and Economic Supplement (ASEC) of Current Population Survey (CPS). The ASEC supplement weights were used to construct the aggregate counts.

Figure 2: High-Speed Internet Installation Diagram

(a) Single Family Home

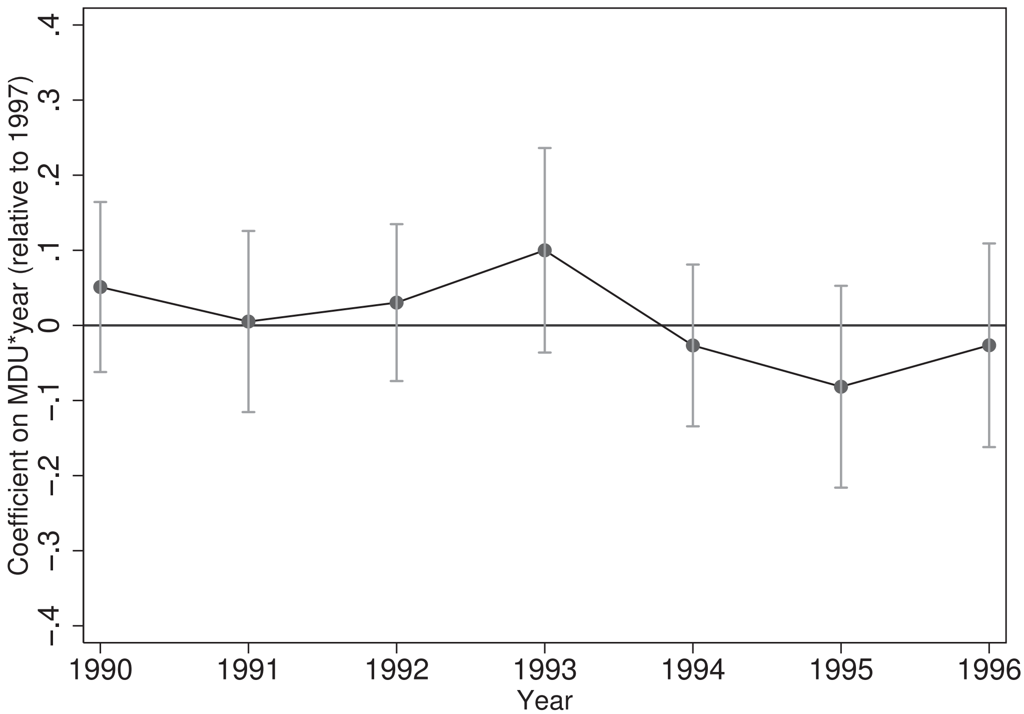


(b) Multiple Dwelling Unit (MDU)



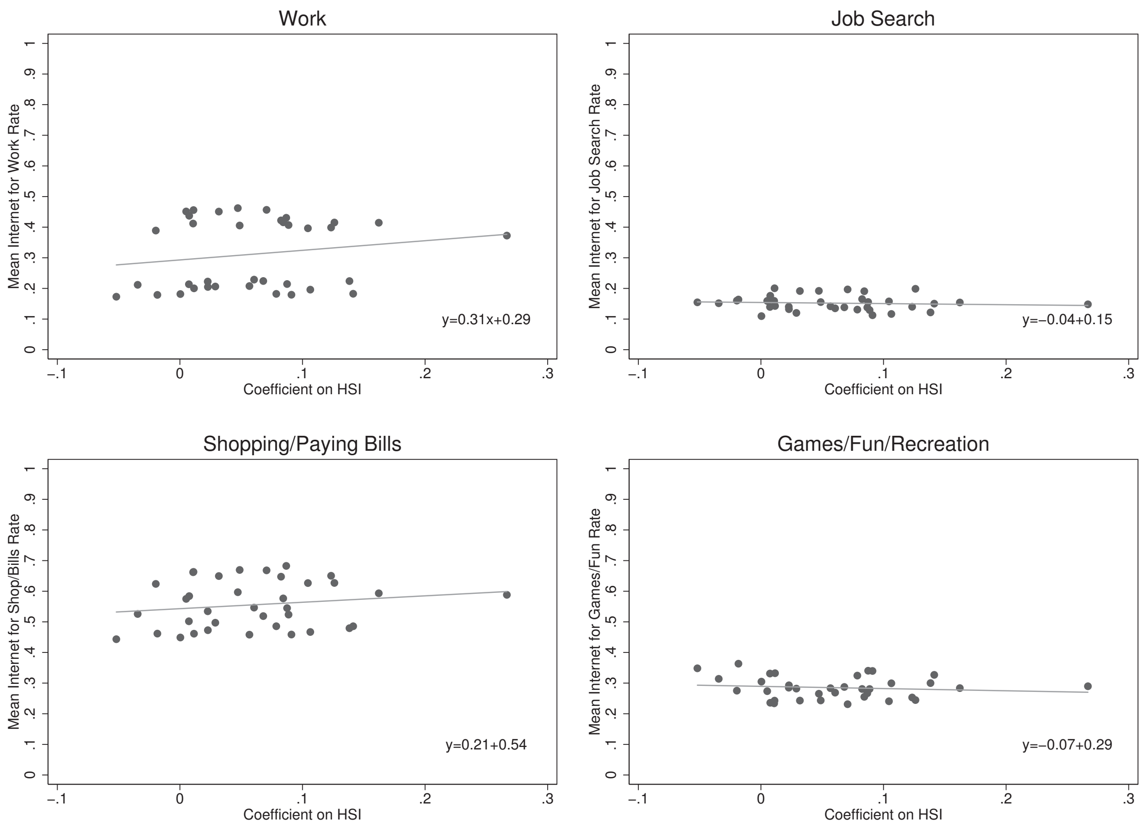
Notes: Author's rendering based on information found in Jackson (2002) and Ames (2006). ISP refers to the high-speed Internet service provider.

Figure 3: Placebo: Reduced Form Relationship between MDU Rates and Labor Supply 1990-1997



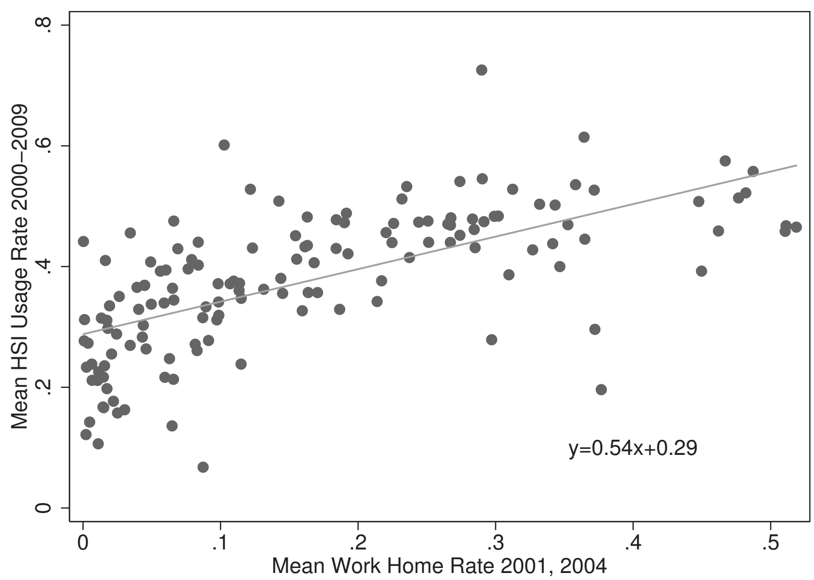
Notes: Displayed are the coefficients and 95 percent confidence intervals on the vector $MDU_s * \theta_t$ from estimation of the reduced form version of equations (1) and (2), which relates the instrument to labor force participation for 1990 to 1996 for the sample of married women. All control variables included in equations (1) and (2) were matched by state and year for the 1990 to1997 time period. Coefficients are relative to the base year of 1997. 1990 to 1997 is the time period prior to the introduction of residential high-speed Internet access.

Figure 4: Group Mean Predicted Change in Participation and Rates of Internet Use for Different Tasks



Notes: Plotted is subgroup level mean rates of Internet use for each activity listed and coefficients on $HSI_{ist} * Subgroup$, based on estimating equations (1) and (2) for each subgroup, where subgroups are defined by education, the presence of children and Census divisions.

Figure 5: Occupation Work at Home Rates and Internet Usage Rates



Notes: Plotted are occupation-specific work at home rates and occupation-specific high-speed Internet usage rates. Only occupations with at least 100 observations are shown and rates are calculated for working, married women 18 to 59. Internet usage rates were calculated in the 2000, 2001, 2003, 2007, and 2009 Current Population Survey supplements used in the main analysis and work at home rates were calculated in the 2001 and 2004 Current Population Survey work schedule supplements.

Table 1: Summary Statistics

Individual-Level CPS Variables:	Mean	SD		Mean	SD
high-speed Internet Use	0.337	0.473	Female	0.514	0.500
2000	0.089	0.217	Married	0.576	0.499
2001	0.103	0.304	Less than HS	0.113	0.316
2003	0.227	0.227	High School	0.311	0.463
2007	0.622	0.484	Some College	0.298	0.457
2009	0.745	0.436	College	0.190	0.392
			Post-Graduate	0.088	0.283
Labor Force Particpation	0.806	0.396	Has Children	0.612	0.487
Married Women	0.730	0.444	Has Child <6	219	0.414
Single Women	0.762	0.426	Lives in MSA	0.733	0.442
Men	0.872	0.334	Lives in Central City	0.232	0.422
			Age	38.91	11.71
Hours Worked	37.51	11.21	White (NH)	0.728	0.445
Full Time	0.545	0.498	Black (NH)	0.095	0.293
Hours>50	0.165	0.372	Hispanic	0.113	0.317
Employed	0.706	0.498	Other (NH)	0.063	0.243

State-Level Variables:	Mean	SD	Data Source
Income Per Capita	39.18	5.927	Bureau of Economic Analysis (BEA)
Average Wage	44.25	7.469	BEA
Population Density	163.15	504.5	Census Land Area and Population Estimates
House Price Index	353.4	112.0	Federal Housing Finance Agency
Unemployment Rate	5.500	2.058	Bureau of Labor Statistics
Percent Adopt	0.904	0.007	Forman et al (2005) and BEA
Percent Enhance	0.130	0.004	Forman et al (2005) and BEA
MDU Rate	0.236	0.0560	2000 Census

Notes: Displayed are means and standard deviations of the individual-level dependent and independent variables from the 2000 to2009 Current Population Survey (CPS) supplements, and the state-level control variables from various sources (as noted). The CPS sample is limited to adults age 18 to 59. Full time status and hours worked are conditional upon participation in the labor market. The number of observations is 368,507.

Table 2: First Stage Estimates

Dependent Variable: HSI Use	
MDU*2000	0.573***
	(0.101)
MDU*2001	0.572***
	(0.104)
MDU*2003	0.544***
	(0.0945)
MDU*2007	0.161**
	(0.0747)
N	368507

Notes: Sample is adults 18 to 59 in the Current Population Survey. Model includes fixed effects for sex, marital status, age category, race/ethnicity, number of children, having a child less than 6, living in an MSA, living in the central city of an MSA, as well as the state level controls in table 2. The omitted category is MDU*2009. Standards errors adjusted for clustering at the state level are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 3: Effect of high-speed Internet on Labor Force Participation

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
Dependent Variable: Labor Force Participation							
HSI	0.043363***	-0.003940	-0.048678	-0.002727	-0.028330	-0.015352	-0.030380
	(0.002173)	(0.086511)	(0.081267)	(0.076179)	(0.089906)	(0.066600)	(0.063181)
HSI*Woman			0.035049***				
			(0.010675)				
HSI*Woman(Married)				0.064852***	0.069420***		
				(0.011813)	(0.011066)		
HSI*Woman(Single)				-0.009845			
				(0.011064)			
HSI*Woman(Married,College)						0.072789***	
						(0.015024)	
HSI*Woman(Married,HS)						0.067092***	0.067584***
						(0.010613)	(0.010703)
HSI*Woman(Married,College,Children)							0.082411***
							(0.016383)
HSI*Woman(Married,College,Childless)							0.068709***
							(0.017572)
F-Stat HSI Use	.	10.37	10.15	10.37	10.38	10.38	10.39
F-Stat HSI*Group 1	.	.	10.37	20.13	20.15	8.27	9.47
F-Stat HSI*Group 2	.	.	.	0.50	.	5.97	4.03
F-Stat HSI*Group 3	.	.	.	.	.	.	5.97
N	368507	368507	368507	368507	368507	368507	368507

Notes: Sample is adults 18 to 59 in the Current Population Survey. All specifications include fixed effects for sex, marital status, age category, race/ethnicity, number of children, having a child less than 6, living in an MSA, living in the central city of an MSA, and group of interest, as well as the state level controls in table 2. The instrument is percent of state living in a multiple dwelling unit (MDU), interacted with the year fixed effects and in columns (3)-(7), fixed effects for the demographic group of interest. Standards errors adjusted for clustering at the state level are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 4: Effect of high-speed Internet on Hours and Employment Status

	(1) Hours	(2) Full-Time	(3) 50+ Hours	(4) Employed	(5) Unemployed
HSI	2.659937	0.053401	0.090606	-0.058401	0.030071
	(2.570060)	(0.097182)	(0.061953)	(0.092367)	(0.020602)
HSI*Woman(Married)	1.249686***	0.036990***	0.012311*	0.087067***	-0.017647***
	(0.267763)	(0.009536)	(0.006803)	(0.011356)	(0.002625)
F-Stat HSI Use	15.09	15.09	15.09	10.38	10.38
F-Stat HSI*Woman(Married)	26.58	26.58	26.58	20.15	20.15
N	256901	281998	256901	368507	368507

Notes: Sample is adults 18 to 59 in the Current Population Survey. All specifications include fixed effects for sex, marital status, an indicator for being a married woman, age category, race/ethnicity, number of children, having a child less than 6, living in an MSA, living in the central city of an MSA, as well as the state level controls in table 2. The instrument is percent of state living in a multiple dwelling unit (MDU), interacted with the year fixed effects and an indicator for being a married woman. Standards errors adjusted for clustering at the state level are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 5: Robustness Checks

	(1)	(2)	(3)	(4)
	$State_{s2000} * \theta_t$	$Z = MDU * Pre$	$Z = 5 + Units * \theta_t$	$Z = 2 + Units * \theta_t$
HSI	-0.037724	-0.066342	0.008443	-0.155227
	(0.145432)	(0.092897)	(0.091201)	(0.134631)
HSI*Woman(Married)	0.069483***	0.104257***	0.068717***	0.071172***
	(0.013611)	(0.025607)	(0.011717)	(0.011828)
F-Stat HSI Use	8.49	22.91	11.90	11.90
F-Stat HSI*Woman(Married)	47.80	97.45	58.99	58.99
N	368507	368507	368507	368507

Notes: Sample is adults 18 to 59 in the Current Population Survey. All specifications include fixed effects for sex, marital status, an indicator for being a married woman, age category, race/ethnicity, number of children, having a child less than 6, living in an MSA, living in the central city of an MSA, as well as the state level controls in table 1. The instrument is percent of state living in a multiple dwelling unit (MDU), interacted with the year fixed effects and an indicator for being a married woman. Standards errors adjusted for clustering at the state level are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 6: Telework Usage by Group

	Work Home	Work Home Once Per Week+	Days Work Home	Days Home Only	Hours Worked at Home	Work Home for Family Reasons
Women (Married)	0.239	0.811	3.480	1.231	12.998	0.069
	(0.006)	(0.006)	(0.029)	(0.030)	(0.231)	(0.004)
Women (Married, College, Children)	0.442	0.830	3.274	0.709	9.442	0.085
	(0.013)	(0.010)	(0.048)	(0.040)	(0.299)	(0.007)
Women (Single)	0.164	0.763	3.282	1.010	10.861	0.045
	(0.007)	(0.008)	(0.040)	(0.037)	(0.282)	(0.004)
Men	0.195	0.808	3.283	0.922	11.089	0.041
	(0.005)	(0.005)	(0.025)	(0.022)	(0.170)	(0.002)

Notes: Displayed is mean and standard error of various measures of working from home. The first column includes all full time working adults 18 to 59. The rest of the columns include only those individuals who report working from home. N also refers to number of individuals in cell who work from home. Source: 2001 and 2004 Current Population Survey.

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Table 7: Full-time Telework, Self-Employment and Internet Job Search

	(1) Full-Time Teleworker (2SIV)	(2) Self-Employed (IV)	(3) LFP (t+1) (LPM)	(4) LFP Hazard (Duration)
HSI	-0.008007	-0.043668		
	(0.006153)	(0.039687)		
HSI*Woman(Married)	-0.003016***	-0.000682		
	(0.001068)	(0.000786)		
InternetJobSearch			0.124697***	0.376836***
			(0.022146)	(0.067009)
InternetJobSearch*Woman(Married)			0.029621	0.047907
			(0.032398)	(0.094637)
N	4891841	368507	6737	6384

Notes: In column (1) the first stage is estimated using equation (1) in the CPS and the second stage is estimated in the ACS. Columns (2) is estimated using equations (1) and (2) in the CPS. Columns (3) and (4) are based on matched waves of the CPS. Dependent variables are described by the first row of the column headings, and the model used is described by the second row of the column headings. All specifications control for sex, marital status, an indicator for being a married woman, age category, race/ethnicity, number of children, having a child less than 6, living in an MSA, and living in the central city of an MSA. Columns (1) and (2) also control for the state level variables in table 2. Standard errors are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 8: Time Use: Differences Between high-speed Internet Users and Non-Users

		Home Production	Leisure
Women (Married)	Difference	-1.78	0.32
	Mean	22.87	27.99
Women (Married, College, Children)	Difference	-2.81	2.00
	Mean	22.02	24.27
Women (Single)	Difference	-3.05	1.20
	Mean	18.33	32.10
Men	Difference	0.45	-3.32
	Mean	15.30	34.30

Notes: Sample includes adults 18 to 59 who are currently employed full time. For each group, the top row displays the difference between high-speed Internet users and non-users in hours per week spent in each activity. The bottom row displays the group mean hours per week spent in each activity.

Appendix

Internet use is available in the October 1997, 2003, 2007, and 2009 school enrollment supplements and the December 1998, August 2000, and September 2001 Current Population Survey Computer and Internet use supplements. In each case, Internet users are identified individually, while the type of connection is at the household level. In 1997 and 1998, household broadband connectivity is not identified, so those supplements are not used. The exact process for identifying Internet users changes slightly over time due to the nature of the questions asked in each supplement. In 2000, 2001 and 2003, individual home Internet usage was based on a individual-level home Internet use recode, which is based on a series of questions for each member of the household roster of the format “Does NAME/do you use the Internet at home for...?”. For 2007 and 2009, individual home Internet usage is defined based on whether the individuals is deemed to be both (1) in a household in which someone uses Internet at home and (2) an Internet user himself (at any location). In all years, the type of connection is identified at the household level. high-speed access is defined as NOT using “regular, or ’dial-up’ service.” In 2000, the survey specifically asked if users had “Higher speed Internet access service”, whereas in following surveys users were asked if they had some combination of “Cable, DSL, fiber optics, satellite, wireless (such as Wi-Fi), mobile phone or PDA, or some other broadband Internet connection.” I opt to define broadband as “not dial-up” because that is how the CPS defines high-speed access, which can be determined from the universe of respondents to a question in 2001, 2003, and 2009 surveys that asked “What is the main reason that you do not have high-speed (that is, faster than dial-up) Internet access at home?”

Table A.1: State Characteristics in 2000

State	% MDU	Population Density	Income Per Capita	House Price Index	Unemp Rate	Avg Wage Income	Percent Adopt	Percent Enhance
DISTRICT OF COLUMBIA	47.04%	4658.4	$51,237	309.8	5.7	$65,517	88.06%	14.12%
NEW YORK	36.73%	201.2	$43,843	436.2	4.5	$56,557	90.14%	13.63%
NEVADA	33.41%	9.2	$39,226	240.3	4.5	$42,099	92.48%	13.09%
SOUTH CAROLINA	30.66%	66.8	$31,754	295.2	3.6	$35,718	90.52%	12.20%
NEW MEXICO	29.79%	7.5	$28,803	252.2	5.0	$35,571	90.52%	12.75%
FLORIDA	29.24%	148.8	$36,823	260.7	3.8	$39,307	90.84%	12.84%
ARIZONA	27.65%	22.7	$33,295	255.7	4.0	$41,586	91.30%	13.21%
CALIFORNIA	27.29%	109.0	$42,299	342.2	4.9	$51,755	91.23%	13.87%
NORTH CAROLINA	27.21%	83.0	$35,337	296.8	3.7	$39,557	90.94%	12.73%
GEORGIA	26.37%	71.0	$36,141	295.7	3.5	$43,457	90.74%	13.04%
TEXAS	25.63%	40.0	$36,097	204.9	4.4	$43,582	90.96%	13.16%
HAWAII	25.62%	94.5	$36,753	291.7	4.0	$38,899	89.35%	12.49%
ALABAMA	25.59%	43.9	$30,476	264.6	4.1	$36,084	90.74%	12.55%
MISSISSIPPI	25.51%	30.4	$27,295	231.0	5.7	$31,926	90.31%	12.25%
MASSACHUSETTS	25.40%	405.7	$48,400	532.2	2.7	$54,801	89.45%	13.56%
OREGON	25.06%	17.9	$36,378	316.9	5.1	$41,504	90.50%	13.18%
WASHINGTON	24.85%	44.4	$41,041	344.9	5.0	$47,544	90.90%	13.27%
ALASKA	24.55%	0.5	$38,632	215.6	6.2	$44,329	88.43%	11.98%
WYOMING	24.51%	2.5	$37,053	192.5	3.8	$34,367	90.54%	12.36%
KENTUCKY	24.21%	51.0	$31,385	279.0	4.2	$35,769	90.65%	12.57%
NORTH DAKOTA	24.13%	4.7	$32,407	205.3	2.9	$30,919	90.55%	12.55%
LOUISIANA	24.05%	51.3	$29,826	203.2	5.0	$35,276	89.92%	12.40%
WEST VIRGINIA	23.88%	37.5	$28,078	199.4	5.5	$33,433	90.24%	12.30%
RHODE ISLAND	23.71%	502.6	$37,353	365.0	4.2	$41,062	89.11%	12.59%
MONTANA	22.96%	3.1	$29,703	267.3	4.8	$30,609	90.25%	12.36%
ARKANSAS	22.83%	25.7	$28,585	228.5	4.2	$33,291	91.01%	12.60%
ILLINOIS	22.81%	111.9	$41,338	311.6	4.5	$48,057	91.10%	13.42%
COLORADO	22.55%	20.9	$43,036	340.2	2.7	$46,930	91.47%	13.63%
TENNESSEE	22.26%	69.2	$33,796	272.8	4.0	$38,045	90.89%	12.76%
MAINE	22.10%	20.7	$33,809	359.1	3.3	$35,203	89.71%	12.45%
NEW HAMPSHIRE	21.36%	69.1	$43,183	348.2	2.7	$43,055	89.86%	13.22%
SOUTH DAKOTA	21.29%	5.0	$33,457	251.5	2.7	$30,895	90.28%	12.58%
VIRGINIA	20.99%	89.7	$40,058	296.4	2.3	$44,658	91.10%	13.46%
DELAWARE	20.96%	201.3	$39,267	338.1	3.3	$45,357	91.33%	13.66%
NEW JERSEY	20.91%	568.3	$48,964	363.1	3.7	$54,403	91.27%	13.71%
CONNECTICUT	20.76%	352.1	$53,083	341.3	2.3	$56,364	90.69%	13.57%
VERMONT	20.15%	33.0	$35,704	318.8	2.7	$35,750	89.26%	12.82%
IDAHO	19.89%	7.9	$31,258	248.4	4.6	$34,898	90.62%	12.97%
OKLAHOMA	19.67%	25.2	$31,153	184.3	3.1	$34,403	90.76%	12.88%
MARYLAND	18.29%	271.7	$43,913	305.0	3.6	$46,364	90.50%	13.00%
MISSOURI	18.25%	40.7	$35,311	267.1	3.3	$39,705	90.52%	13.06%
MINNESOTA	17.23%	31.0	$41,280	294.2	3.1	$43,970	90.96%	13.47%
UTAH	16.85%	13.7	$31,043	300.5	3.4	$37,125	90.50%	13.52%
OHIO	16.83%	138.8	$36,336	275.9	4.0	$41,039	91.04%	12.97%
INDIANA	16.65%	84.9	$34,771	262.1	2.9	$39,216	90.94%	12.68%
MICHIGAN	16.07%	87.6	$37,229	325.7	3.7	$46,126	91.43%	12.96%
WISCONSIN	15.89%	49.5	$36,901	290.2	3.4	$38,726	90.99%	12.90%
KANSAS	15.82%	16.5	$36,049	227.5	3.8	$37,200	90.96%	13.01%
NEBRASKA	15.65%	11.1	$36,203	257.1	2.8	$36,041	90.41%	12.98%
PENNSYLVANIA	14.67%	137.0	$38,132	300.3	4.2	$42,218	89.85%	12.91%
IOWA	14.61%	26.2	$34,551	238.1	2.8	$34,631	90.24%	12.67%