Evolution of Advanced Econometric Modeling in Prediction of Technology Adoption: Case Study of Telework Market Penetration

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Abstract

Application of econometric models has a rich background in different aspects of policy analysis and management fields. In particular, the concept of "market penetration", which investigates how well a management policy is welcomed and adopted in the market, is an index of policy success. Thus, employing powerful statistical approaches which are capable of providing reliable results, is intrinsically of the essence for policy planners and decision makers. This study provides a comprehensive review of statistical approaches used in a special case of work arrangement policy in organizations, known as "telecommute" or "telework". This paper delves into the 30 year history of telework policy in the US and all over the world, and investigates the modeling techniques and statistical tools which have been used to predict potential market share of telework adoption. A detailed summary of modeling techniques, variables and contributing factors, popular statistical issues which need to be taken care of, as well as the impacts of sample size and sample statistics is discussed.

Key words: Econometric modeling, technology adoption, telework, discrete choice analysis, data analysis, predictive analytics

1. Introduction

Telecommuting, has been considered and discussed by researchers and policy planners as an alternative work arrangement in the past twenty to thirty years. In particular, several attempts have been carried out to predict workers' behaviors when they are offered the opportunity to work from home, technically referred to as "telecommuting". This research brief provides a technical summary of methodological efforts conducted in the academia in order to predict market shares of telecommuters among the labor force.

2. Literature Review

The review provided here is based on a comprehensive investigation of methodological and theoretical papers and reports on telecommuting estimation approaches. Accordingly, the dominant methodology is discrete choice modeling which ranges from simple binary or multinomial logit (probit) models to advanced joint modeling structures. In this section, we review the major learnings from the literature in addition to enumerating the details of major publications since late 80s.

The evolution in the development of telecommuting forecast models can be observed from a variety of perspectives, including the following:

2.1. Data

Early telecommuting studies relied on stated preference (SP) data (Bernardino et al., 1993; Yen and Mahmassani, 1994; Mokhtarian and Salomon, 1994). However, inconsistencies were observed between the findings from SP-based data and RP-based analyses. This has led to an overall shift towards revealed preference (RP) data since the mid-90s. (Mannering and Mokhtarian, 1995; Mokhtarian and Salomon, 1997; Popuri and Bhat, 2003). Inconsistencies usually originate from the conceptual gap that exists between the preference to telecommute and actual telecommute adoption. In a telecommuting survey in San Diego California, Mokhtarian and Salomon (1996) showed that 88 percent of 628 survey respondents preferred to telecommute, while only 13 percent actually did.

Data limitation is another fundamental drawback in telecommuting studies, which might manifest in terms of sample size or information resolution. Initially, studies were usually based on small-scale samples from one or two specific organizations (Bernardino et al., 1993; Sullivan et al., 1993; Mannering & Mokhtarian, 1995; Mokhtarian & Salomon, 1994, 1996a, 1996b, 1997; Mokhtarian et al., 1998; Wells et al., 2001, Mamdoohi 2006). These organization-specific databases bring some helpful advantages, in that they usually contain detailed professional and task-related information and attitudinal behaviors of both managers and employees. However, they hamper the generalization of the analysis results and might raise questions on model transferability.

With the above being said, the tendency to utilize statewide or national sample sizes is a major improvement in telecommute forecast models (Drucker & Khattak, 2000; Yen, 2000; Popuri & Bhat, 2003; Walls et al., 2006; Zhou, 2008; Sener & Bhat, 2011; Singh et al., 2012).

2.2. Telecommuting Definition

Preliminary studies rarely presented standard definitions of telecommuting activity. The intensity (frequency) of telecommuting, for instance, was defined based on discrete categories with thresholds being study-specific (Mannering & Mokhtarian, 1995; Mokhtarian et al., 1998; and Walls et al., 2006). The fact that classification criteria were different from one study to another would lead to several confusions, specifically when it came to results comparison among different studies. Several solutions have been proposed, e.g. some researchers suggested using the number of telecommuting days (either per week or per month) as a frequency instead of discrete categories (Popuri & Bhat, 2003; Sener & Bhat, 2011; Singh et al., 2012). Another problem was that researchers did not differentiate between home-based workers (those who do not have a physical workplace outside home) and those who have a fixed office but do work at home instead of commute to work (real telecommuters).

Providing clear definitions of telecommuters and their subcategories, could be named as major enhancements of models in the research background.

2.3. Multiple Dimensions

It should be noticed that telecommuting, just like any other behavioral decision-making process, is a complicated multidimensional phenomenon and could be viewed from several perspectives. Early studies mainly emphasized on “preference” and “choice” (Sullivan et al., 1993; Bernardino et al., 1993; Mokhtarian & Salomon, 1994, 1996a, 1996b, 1997; Mokhtarian et al., 1998; Belanger, 1999; Wells et al., 2001; Grippaldi, 2002). Other dimensions including “frequency”, which denotes the intensity of telecommuting activity, or “option”, which is an index of the availability of telecommuting opportunity at work, were later added to the literature (Mannering & Mokhtarian, 1995; Drucker & Khattak, 2000; Yen, 2000; Peters et al., 2004; Popuri & Bhat, 2003; Wernick, 2004; Walls et al., 2006; Mamdoohi et al., 2006; Zhou, 2008; Vana et al., 2008; Haddad et al., 2009; Tang et al., 2011; Sener & Bhat, 2011; Singh et al., 2012). Some researchers have discussed the role of short-term daily dimensions of telecommuting in comparison with long-term (lifestyle) dimensions (Asgari et al. 2014, Asgari and Jin 2015, Asgari et al. 2016).

2.4. Different Adoption Forms

Telecommuting can be performed in a number of distinctive ways. It could be done on a full-time basis where the worker telecommutes on every single day of the week or it could be part-time where the person may telecommute only on some specific days. Even on a random day, a worker may adopt full-day or part-day telecommuting. Full-day is referred to the situation that the worker totally works from home (i.e. the commute trip is removed) while part-day telecommuter is one who splits the daily work between home and workplace during the day (the commute trip still exists but can be shifted). Furthermore, a worker can have a “regular” long-term telecommuting schedule which is woven into his/her lifestyle while “non-regular” telecommuters are those who may randomly telecommute on a specific day with no long-term decision for that.

Early studies latently assumed that telecommuting is a regular full-day arrangement, while recent researchers have distinguished between part-day and full-day workers, specifically through the fact that the impacts of the two policies are totally different on the traffic network (De Graaf & Rietveld 2004, Lyons et al. 2006, Lyons and Haddad 2008, Haddad et al. 2009, Asgari & Jin 2015).

2.5. Modeling Techniques

Similar to any other field of science, telecommuting studies have been influenced by technical improvements in statistical knowledge and predictive analytics. Early studies mainly focused on descriptive statistics and simple models such as Multinomial or binary logit structures, however the literature has been gradually enriched through application of sophisticated econometric tools and methodologies. Details could be viewed in Table 1.

2.5. Evolution of Variables

In general, telecommuting behavior can be explained based on socio-economics and demographics as well as individual and household characteristics. In presence of detailed organizational information, job-related parameters and managerial attitudes can also be incorporated to the model. Inclusion of the latter is not easily feasible as accessing those parameters requires identification of different types of employers' strategies, and collecting high resolution data through detailed work-related surveys. Doing this at large scale implies high expenses in terms of both time and money. Hence such surveys usually focus on small sample sizes. Research studies that deal with relatively huge sample sizes are likely to use general job-related variables, which could be simply obtained from national or statewide surveys. In some cases, accessibility, land-use, and built environmental variables are also included in the model.

3. Conclusion

This research report provides a summary of applied methodologies in the field of telecommuting forecast. As discussed, the dominant approach is discrete choice models, which range from simple structures to complicated statistical frameworks. Based on the findings, telecommuting is a multi-dimensional concept which can be adopted in different forms. The definition of telecommuting has evolved through the years and found a stable standard format. Telecommuting behavior can be predicted based on socioeconomic and demographic attributes as well as job-related parameters. There is a tendency to use national/statewide data surveys for telecommuting studies in order to improve models' transferability.

Table 1. Summary of Literature Review

Publication	Methodology/Econometric Modeling techniques	Sample Size	Telecommuting Dimensions
Sullivan et al. 1993	Multinomial Logit Model	554	Preference
Bernardino et al. 1993	Ordered Response Probit Model	554	Preference
Mokhtarian & Salomon 1994	Descriptive statistics & Correlation Analysis	628	Preference & Choice
Mokhtarian & Salomon 1995	Binary Logit Model	628	Preference & Choice
Mannering & Mokhtarian 1995	Multinomial Logit Model	809	Frequency
Mokhtarian & Salomon 1997	Binary Logit Model	628	Preference
Mokhtarian et al. 1998	Descriptive statistics & Correlation Analysis, Hypothesis testing	628	Preference
Belanger 1999	Descriptive statistics & Correlation Analysis, Hypothesis testing	71	Choice
Yen 2000	Ordered Probit Model	2715	Choice & Frequency
Drucker & Khattak 2000	Oredered Logit, Ordered probit, Multinomial Logit	29'994	Choice & Frequency
Wells et al. 2001	Descriptive statistics & Correlation Analysis, Hypothesis testing	797	Preference
Grippaldi 2002	Descriptive statistics & Correlation Analysis, Factor Analysis	400	Preference
Popuri & Bhat 2003	Joint Sample Selection Model (Binary & Ordered Bivariate Probit)	6532	Choice & Frequency
Peters et al. 2004	Binary Logit Model	849	Option, preference & choice
Wernick 2004	Binary & Ordered Logit Model	23451	Choice & Frequency
Walls et al. 2006	Two- Staged Model (Binary & Ordered probit)	2448	Choice & Frequency
Mamdoohi et al. 2006	Nested Logit, Multinomial Logit	245	Option
Zhou 2008	Generalized Oredered Logit Model	92'321	Choice & Frequency
Vana et al 2008	Nested Logit, Multinomial Logit, Mixed Multinomial logit	305	Frequency
Haddad et al. 2009	Ordered Probit Model	570	Choice & Frequency
Tang et al. 2011	Nested Logit, Multinomial Logit, Two-staged	1064	Choice & Frequency
Sener & Bhat 2011	Copula Based Joint Sample Selection Model (Binary & ordered bivariate probit)	9624	Choice & Frequency
Singh et al. 2012	Joint Sample Selection Model (Binary & Ordered Probit)	2563	Option, Choice & Frequency
Asgari et al. 2015	Joint Sample Selection Model (Binary & Ordered Probit)	15844	Choice, Frequency, Daily Engagement, Additional Commute

References

Asgari, H. and X. Jin (2015). 'Analysis of Telecommuting Behavior: Substitution or Supplementary? Combining Lifestyle Choice with Daily Engagement'. TRB 94th Annual Meeting Compendium of Papers, Paper#15-0283.

Asgari, H., and X., Jin (2015). 'Towards a Comprehensive Telecommuting Analysis Framework; Setting the Conceptual Outline", Transportation Research Record, Journal of Transportation Research Board, No. 2496, pp.1-9.

Asgari, H., Jin, X. & A. Mohseni (2014). 'Choice, Frequency, and Engagement – A Framework for Telecommuting Behavior Analysis and Modeling'. Transportation Research Record: Journal of the Transportation Research Board, No. 2413, pp. 101-109.

Asgari, H., X., Jin and Y. Du (2016). 'Examining the Impacts of Telecommuting on the Time-Use of Non-Mandatory Activities', Transportation Research Record (TRR), Journal of the Transportation Research Board, No. 2566, DOI: 10.3141/2566-09, in press.

Asgari, H., X., Jin and Y. Du (2016). 'Examining the Impacts of Telecommuting on the Time-Use of Non-Mandatory Activities', Transportation Research Board 95th Annual Meeting Compendium of Papers, Paper#16-1659.

Asgari, H., X., Jin and Y. Du (2016). 'Investigation of Commute Departure Time to Understand the Impacts of Part-Day Telecommuting on the Temporal Displacement of Commute Travel', TRB 95th Annual Meeting Compendium of Papers, Paper#16-1662.

Asgari, Hamidreza, "On the Impacts of Telecommuting over Daily Activity/Travel Behavior: A Comprehensive Investigation through Different Telecommuting Patterns" (2015). *FIU Electronic Theses and Dissertations.* Paper 2182.
http://digitalcommons.fiu.edu/etd/2182

Belanger, F., 1999. "Workers' Propensity to Telecommute: An Empirical Study". Journal of Information and Management, 35(3), pp. 139-153.

Bernardino, A., Ben Akiva, M. and I. Salomon, 1993. "Stated Preference Approach to Modeling the Adoption of Telecommuting". Transportation Research Record, 1413, pp. 22-30.

De Graaf, T., and P. Rietveld, 2004, "ICT and substitution between out-of-home and at-home work: the importance of timing" Environment and Planning A 36(5) 879 – 896.

Drucker, J. and A.J. Khattak, 2000. "Propensity to Work from Home: Modeling Results from the 1995 Nationwide Personal Transportation Survey". Transportation Research Record, 1706, pp. 108-117.

Grippaldi, Joseph J., 2002. "An Empirical Study of Attitudes towards Telecommuting among Government Finance professionals". UNLV Theses/Dissertations/Professional Papers/Capstones. Paper 515.

Haddad, H., Lyons, G. and K. Chatterjee, 2009. "An Examination of Determinants Influencing the Desire for and Frequency of Part-day and Whole-day Homeworking", Journal of Transport Geography, 17, pp. 124-133.

Lyons, G., Haddad, H., 2008. Commute displacement or commute replacement: the rise of part-day homeworking. Paper presented at the 87th Annual Meeting of the Transportation Research Board, January, Washington DC.

Lyons, G., Haddad, H., Jones, T., 2006. Introducing consideration of varied spatio temporal workers to the study of teleworking. In: Paper Presented at the 11th International Conference on Travel Behaviour Research, August, Kyoto.

Mamdoohi, A.R., Kermanshah, M. and H. Poorzahedy, 2006. "Telecommuting Suitability Modeling: An Approach Based on the Concept of Abstract Job". Transportation, 33, pp. 329-346.

Mannering, J.S. and P.L. Mokhtarian, 1995. "Modeling the Choice of Telecommuting Frequency in California; An Exploratory Analysis". Technological Forecasting and Social Change, 49, pp. 49-73.

Mokhtarian, P. L. and I. Salomon, 1994. "Modeling the Choice of Telecommuting: Setting the Context". Environment and Planning A 26(5), pp. 749-766.

Mokhtarian, P. L. and I. Salomon, 1996. "Modeling the Choice of Telecommuting 2: A Case of Preferred Impossible Alternatives". Environment and Planning A 28, pp. 1859-1876.

Mokhtarian, P. L. and I. Salomon, 1996. "Modeling the Choice of Telecommuting 3: Identifying the Choice Set and Estimating Binary Choice Models for Technology-Based Alternatives". Environment and Planning A 28, pp. 1877-1894.

Mokhtarian, P. L. and I. Salomon, 1997. "Modeling the Desire to Telecommute: The Importance of Attitudinal Factors in Behavioral Models", Transportation Research A 31(1), pp. 35-50.

Mokhtarian, P.L., Bagley, M.N. and I. Salomon, 1998. "The Impact of Gender, Occupation and Presence of Children on telecommuting Motivations and Constraints". Journal of the American Society for Information Science, 49(12), Special Issue on Social Informatics, pp. 1115-1134.

Peters, P., Tijdens, K.G. and C. Wetzels, 2004. "Employees' Opportunities, Preferences, and Practices in Telecommuting Adoption", Journal of Information and Management, 41, pp. 469-482.

Popuri, Y., and C.R. Bhat, 2003. "On Modeling Choice and Frequency of Home-Based Telecommuting". Transportation Research Record, 1858, pp. 55-60.

Sener, I.N. and C.R. Bhat, 2011. "A Copula-Based Sample Selection Model of Telecommuting Choice and Frequency". Environment and Planning A, 43(1), pp. 126-145.

Singh, P., Paleti, R., Jenkins, S. and C.R. Bhat, 2012. "On Modeling of Telecommuting Behavior: Option, Choice and Frequency". Transportation, 40(2), pp. 373-396.

Sullivan, M.A., Mahmassani, H.S. and J.R. Yen. 1993. "Choice Model of Employee Participation in Telecommuting under a Cost-Neutral Scenario". Transportation Research Record, 1413, pp. 42-48.

Tang, W., Mokhtarian, P.L. and S.L. Handy, 2011. "The Impact of the Residential Built Environment on Work at Home Adoption and Frequency: An Example from North California". Journal of Transport and Land Use, 4(3), pp. 3-22.

Vana, P., Bhat, C.R. and P.L. Mokhtarian, 2008. "On Modeling the Choices of Work-Hour Arrangement, Location and Frequency of Telecommuting". Research Report, UCD-ITS-RR-08-48.

Walls, M., Safirova, E. and Y. Jiang, 2006. "What Drives telecommuting? The Relative Impact of Worker Demographics, Employer Characteristics, and Job Types". RFF-DP-06-41, Resources for the Future.

Wells, K., Douma, F., Loimer, H., Olson, L. and C. Pansing, 2001. "Telecommuting Implications for Travel Behavior, Case Studies from Minnesota". Transportation Research record, 1752, pp. 148-156.

Wernick, S., 2004. "Telecommuting: Working from Home in 21st Century". Master's degree Project, Department of City and Regional Planning, University of North Carolina Chapel Hill.

Yen, J. R. and H. S. Mahmassani, 1994. "The telecommuting Adoption Process: Conceptual Framework and Model Development", Research Report SWUTC/94/60055-1, Center for Transportation Research, University of Texas at Austin.

Yen, J.R., 2000. "Interpreting Employee Telecommuting Adoption: An Economic perspective". Transportation, 27, pp. 149-164.

Zhou, L, 2008. "Modeling the Impacts of An Employer Based Travel Demand Management Program on Commute Travel Behavior", Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of South Florida.