H-062 Research on Evaluation for Design and Achievement of Sustainable Development Scenario with Cooperation between Institution and Technology (Abstract of the Final Report)

Contact person   Saijo Tatsuyoshi

Professor, Institute of Social and Economic Research, Osaka University

6-1 Mihogaoka, Ibaraki, Osaka, 560-0047 Japan

Tel: +81-6-6879-8582 Fax:+81-6-6878-2766

E-mail: saijo@iser.osaka-u.ac.jp

Abstract

In the current study, both institutional design specialists and environmental engineering researchers have been working together to construct the framework of institutional design that supports the adoption and dissemination of the most adaptive technology responding to regional characteristics and to make suggestions regarding the methodology of institutional design for achieving the scenario roadmap of technologies' development and dissemination. Our analyses focused mainly on such sensitive topics as (i) the evaluation of the role of current environmental policy playing in environmental-friendly technology dissemination; (ii) the development of a case model of "cooperation between institution and technology" to prompt sustainable technologies; (iii) the evaluation of the effect of the consumers' preference and life style on the future energy demand and material flow; and (iv) the application of sustainability indicators for the assessment of social systems comprising technologies, institution and industrial activities, etc. From our study, the possibility of success in the policy of feed-in tariff in both China and Japan was predicted. In addition, we also found that image strategy is an important factor for the dissemination of pro-environmental machines in Japan, while comparing to other factors, policy of decreasing consumers' initial cost is much more important in China. Moreover, through the evaluation of applying various existing sustainability indices in Shanghai's environmental performance, we provided useful guides for developing applicable sustainability indices in the future. Finally, the current study has made a number of contributions to policy of global environmental issues for decision makers.

1. Introduction

There is no doubt that the development of science and technology is an important key to achieve sustainable development (e.g., greenhouse gas reduction, etc.) through the 21st century. In

this case, in order to reach the target of a sustainable society, not only improving the characteristics of the technology themselves (e.g., price and efficiency, etc.) but also the designs of social institution influencing the effect of technology dissemination are necessary.

However, previous institutional designs aiming at conserving the environment seldom took into account the factors influencing technology dissemination (e.g., consumers' preferences, etc.). On the other hand, from the viewpoint of research and development (R&D) associated with environmental technology, social institutional design, which prompts the popularization of those technologies responding to regional characteristics and appearance of the expected effects, is also required.

2. Research Objective

In the current study, based on the cooperation between institutional design specialists and environmental engineering researchers, we intend to construct the framework of institutional design that supports the adoption and popularization of the most adaptive technology responding to regional characteristics; and make suggestions regarding the methodology of institutional design for achieving the scenario roadmap of technologies' development and popularization. The research content of this study is presented in Fig. 1.
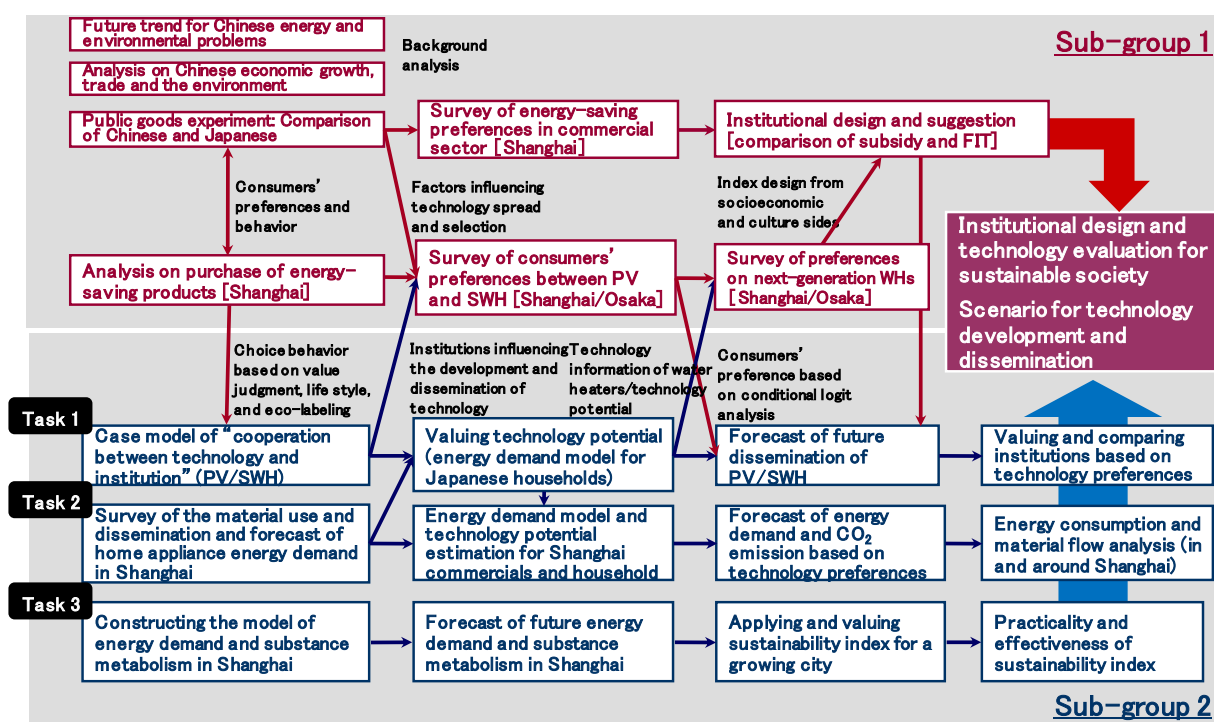

Fig. 1 The research content

3. Research Method

(1) Institution design for environmental conservation based on mutual feedback of theoretical

economics and experimental economics

With a purpose of creating a roadmap for Shanghai of China, we conducted a couple of studies such as (i) the investigation of the current status and future trend for Chinese energy and environmental problems; (ii) the analysis of the simultaneous relationship between economic growth and pollution in China; (iii) the economics experiment aiming at making Chinese choice behavior in public goods investments clear to us; (iv) the questionnaire survey to examine the socioeconomic determinants of individual's environmental concern in China; (v) the investigation of how China Energy Efficiency Label affects consumers' purchasing decision of air-conditioners and refrigerators; (vi) the analysis of the determinants of consumers' choice in solar photovoltaic power generation unit, solar water heater, and other energy-saving water heaters for next-generation; and (vii) the questionnaire survey to examine the relations between energy consumption and extent of energy-saving efforts in commercial sector.

(2) Goal setting of technology development considering institutional condition and evaluation on technology from the viewpoint of sustainability.

This group focused on the technologies which are required for sustainable development such as global warming mitigation and recycle-based society. By referring the results of sub-group (1), decision-support tools for institutional design for environmentally-sound technologies were developed. In addition, evaluation indices for sustainability of urban energy and material metabolism were proposed and examined. For this purpose, following three themes were studied: 1) development of a case model of "cooperation between institution and technology" to prompt sustainable technologies, 2) evaluation of the effect of the consumers' preference and life style on the future energy demand and material flow in the residential sector of Shanghai, and 3) Application of sustainability indicators for the assessment of social systems comprising technologies, institution and industrial activities.

4. Results
(1) Institution design for environmental conservation based on mutual feedback of theoretical economics and experimental economics

1) Results for the researches in FY 2006

We first run the integrated econometrics model including macroeconomics model, energy-demand model, and environmental model to investigate the current status and future trend for Chinese energy problem. The results indicate that Chinese energy consumption would increase to 3.3 billion TOE and SO_2 emission would be 2.6 billion t-C in 2030 if the current policy was maintained. It is obvious to the policy makers that the current energy and environmental policies should be reconsidered, especially for the issues associated with developing energy efficient technologies and prompting international cooperation. The study also suggests that when prompting international cooperation such as technological aids from Japan smoothly, Chinese government should at first solve the serious property right problem, whilst on the other hand, Japanese side

should consider a comprehensive strategy on choosing the adaptive technology according to actual situation of China.

Concerning the study on the relationship between economic growth and environmental problem, we first investigate whether the simultaneous relationship exists in per capita GDP and per capita pollutant emissions. The results indicate that in China, income and pollutant emissions are jointly determined. Based on this result, we therefore apply a simultaneous equations model (SEM) for empirical study. An Environmental Kuznets Curve relationship is found only in water pollutants such as COD, Arsenic in water, and Cadmium in water. In addition, negative effect of pollution on income and positive effect of physical capital and labor on income are also found in income equation. On the other hand, the study examining the relationship between international trade and environmental problem in China adopts the methodology provided by Anteweiler et al. (2001)[1] and slightly modifies their model. The results indicate that increasing international trade has opposite impacts on the environment due to different pollutants. That is for air pollutants increase in international trade leads to more emissions, whilst for water pollutants trade liberalization decreases emissions.

The laboratory experiment conducted in Shanghai aims at investigating Chinese choice behavior in the provision of public goods via the voluntary contribution mechanism. This study adopts the same experimental design as the one used in Saijo and Nakamura (1995)[2], i.e. either cooperating (full contribution) or free riding (no contribution) is predicted as the unique Nash equilibrium with a high (larger than one) or low (smaller than one) marginal return of contribution. Comparing the results of Chinese subjects with their Japanese counterparts, we find significant differences between these two countries in terms of their choice behavior, despite the similarities in their cultures and the proximity in geographical positions. Japanese subjects are more likely to act spitefully, and, in contrast, Chinese subjects are more likely to perform cooperatively. In addition, concerning the deviations from the Nash equilibriums with different marginal returns, the statistical results indicate that Chinese subjects behave more consistent with the theoretical prediction in the high marginal return case, while Japanese choice behavior seems less different from the theoretical expectation in the low marginal return case.

Finally, we examine the influence of socioeconomic characteristics on eleven measures of environmental concern in a pooled survey sample of 1200 individuals in Shanghai, China. Previous studies (e.g. Van Liere and Dunlap (1980)[3] and Fransson and Gärling (1999)[4]) suggest that there are traditionally five hypotheses (the age, gender, social class, residence, and political hypotheses) for socioeconomic determinants associated with environmental concern. In our analysis, high income and high education level are found to be positively related to environmental concern as expected. However, we find that contrast to most of the existing studies, the marginal effect of age on the probability of being environmental concerned is positive in several measures, implying that the older are more concerned about the environment than the younger. In addition, weak evidences indicate that women in Shanghai are less concerned about the environment than men. Other characteristics such as employment status and household are found not significant in most of the environmental concern measures we defined.

2) Results for the researches in FY 2007

The results of running the choice model of energy-labeled air-conditioners and refrigerators indicate that the effect of China Energy Efficiency Label on consumers' preferences is twofold. First, more energy efficient air conditioners and refrigerators are preferred by consumers, no matter whether they are with foreign brands or domestic brands and whether they are new or second-hand. Second, energy efficiency label *per se* is recognized by consumers. These results are consistent to those of the previous studies on eco-label or energy label such as Bjorner et al. (2004)[5]; Teisl et al.(2002)[6]; Loureiro et al.(2002)[7]; Banerjee and Solomon, 2003[8]; and Howarth et al. 2000[9]. In addition, presence of a (hypothetical) label that indicates the electricity bill's difference comparing to a standard model is significantly preferred by the respondents in most of the cases, suggesting that more information provided to consumers makes them much happier. Finally, the class probability weighted willingness to pay values for one rank upgrading in energy efficiency of refrigerator are higher than those of air conditioner, implying that consumers have an incentive to pay for appliances used more frequently.

Concerning the study on the relations between energy consumption and extent of energy-saving efforts in commercial sector of Shanghai, we first formulated an econometrics system, which consists of three equations (i.e., energy consumption equation, energy-saving efforts equation, and energy-saving technology equation), and then applied a three-stage least squares method to estimate the system. The results indicate that in Shanghai, more energy-saving efforts made and more technologies introduced by the commercial factor, less energy (in particular, electrical power) would be consumed. In addition, for those commercial buildings consuming much electrical power, more efforts on energy-saving would be made and more technologies on energy-saving would be introduced. Finally, the results indicate that the commercial buildings with surplus make more efforts and take more technologies in energy-saving. Furthermore, we also find that the old buildings seem difficult to introduce new energy-saving technologies from the estimation.

Finally, we examine the determinants of consumers' choices in solar photovoltaic power generation unit and solar water heater through field surveys in both Shanghai (700 respondents) and Osaka (375 respondents). The results estimated by a conditional logit model suggest that (i) In both Shanghai and Osaka, respondents favor solar photovoltaic power generation unit than normal gas or electrical water heater. In addition, concerning the preference on solar water heater, Shanghai respondents are more likely to prefer than normal gas or electrical water heater. In contrast, Osaka respondents seem no difference between solar water heater and normal gas or electrical water heater. (ii) Both Shanghai and Osaka respondents do not prefer increase in price, which is consistent to economic theory. (iii) Both Shanghai and Osaka respondents prefer to receive more subsidies, suggesting that the subsidy system is plausible in both places. (iv) For the price of selling remained electricity generated by solar photovoltaic power generation unit, Osaka respondents are found to be happier if the price increases, while Shanghai respondents seem not care about this price, suggesting that Feed in Tariff system is potentially useful in Japan. We regard

this result is reasonable because selling electricity is not allowed currently in China.

3)   Results for the researches in FY2008

Based on the results of comparison between solar photovoltaic power generation unit and solar water heater in FY2007, we conducted a face-to-face survey to examine and compare consumers' preferences between Chinese (1620 respondents) and Japanese (700 respondents) on five next-generation energy-saving water heaters (i.e., latent-heat-recovery gas water heater, micro-gas-engine cogeneration system, CO_2 heat pump water heater, solar water heater, and solar system).

We first asked the respondents to choose one favorable water heater from the five machines based only on the photo and information sheet. The result from this simple choice indicates that the ratio choosing solar system (31.33%) is the highest in Japanese respondents, while the ratio choosing solar water heater (50.74%) is the highest in Chinese respondents. It seems that without considering price and other attributes, Japanese respondents prefer a solar system and Chinese respondents prefer a solar water heater.

Then, we conducted the hypothetical choice experiment with various attributes of the five energy-saving water heaters being provided. The results suggest that for both Chinese and Japanese respondents, the preferences on various attributes described by willingness to pay values differ among different water heaters. In addition, we also found that there are large differences between Chinese and Japanese respondents in the preferences on a part of attributes.

Our results imply that in addition to several important factors (e.g., subsidy, FIT, etc.) influencing the choice, change in appearance design and image strategy are also important to Japanese consumers. Moreover, our results also imply that there exists the possibility of quicker dissemination of these energy-saving water heaters in China if such policies as providing subsidy to consumers to reduce consumers' initial cost are provided.

(2)   Goal setting of technology development considering institutional condition and evaluation on technology from the viewpoint of sustainability.

1)   Development of a case model of "cooperation between institution and technology" to prompt sustainable technologies

We took photovoltaic power generation (PV) and thermal solar system as an example to understand how the customers' preference influences diffusion of technologies and to what extent consideration of their preference in institutional design would contribute to disseminating environmentally-friendly technologies. We first reviewed the policies that have been implemented to prompt these technologies in Japan and Europe. Germany has been successful to disseminate PV by implementing a number of policy measures, such as "feed-in tariff" that guarantees economical benefit of PV owners and has boosted the dissemination of PV. On the other hand, dissemination of PV power generation in Japan has been sustained by a high-level willingness-to-pay of PV owners. In Japan, thermal solar system, a competing technology using roof, has decreased its popularity in

recent years, even though thermal solar system has economic rationality. Therefore, we then investigated the preference of consumers for these technologies as well as the influence of the properties of these technologies, such as installation cost, energy price, energy efficiency and image, on the consumers' choice. Taking into account the influence which was modeled using the result of the conditional-logit analysis conducted by the subgroup (1), we developed a model estimating the number of these technologies installed in the residential sector of Japan until 2030. We also developed a detailed end-use energy demand model of the Japanese residential sector to estimate the CO_2 emission reduction gained by the dissemination of these technologies. We found that for dissemination of PV, policy measures reducing the initial cost (e.g. subsidy program) is more cost effective for reducing CO_2 emission compared with those reducing operation expenditure of users (e.g. feed in tariff program), while the image of solar thermal system must be improved so that the technology will become widespread and deliver a considerable amount of reduction.

2) Evaluation of the effect of the consumers preference and life style on the future energy demand and material flow in the residential sector of Shanghai

    We developed an energy demand model of the residential sector of Shanghai city to estimate the energy consumption and carbon dioxide emission (CO_2) until the year 2030 as well as the potential reduction that can be gained by disseminating a variety of energy-conservation technologies (improvement of building insulation, improvement of the energy efficiency of home appliances, replacement of hot-water-supply systems with those with higher energy efficiency). We also estimated the extent to which consumers' preference and attitude to the recovery of investment on these energy-conservation technologies would alter the energy consumption and CO_2 emission of the sector. From the analysis, we reached the following conclusions; (i) If the energy consumption pattern of people in Shanghai would not vary in the future within their income levels, energy consumption would increase by from 30% to 40% due to the increase in the population from that in 2006. (ii) To mitigate the increase, it was crucial to disseminate all the abovementioned-technologies. By fully disseminating all the technologies, the CO_2 emission expected for 2030 can be reduced by approximately 20%. The reduction is equivalent to a 30% of the emission in 2006. (iii) Two-thirds of the CO_2 reduction was estimated to achieve when the consumer preference for the recovery of investment was taken into account.

    On the other hand, there would be a lot of end-of-life products due to the replacement of existing equipments by more energy-efficient ones. In China, the waste home appliances are often reused and recycled informally and it has caused serious environmental pollution. In this research, we estimated the influences of consumption patterns on CO_2 emission and waste generation from the air-conditioner, color television, refrigerator and washing machine in China. The result showed that the future consumption patterns of home appliances could be divided into 4 types based on the result of questionnaire survey in Shanghai and its two neighboring cities (Kunshan and Huzhou). Also we found that the waste products could be reduced by 31% through promoting the cascade reuse, and the renewal of products to more energy-efficient one could reduce CO_2 emission by 18%.

3) Application of sustainability indicators for the assessment of social systems comprising technologies, institution and industrial activities

A quantitative model for urban metabolism was developed to evaluate direct and indirect environmental impacts due to the energy and materials consumption in Shanghai, China. Also we estimated CO_2 emission, Total Material Requirement (TMR) and Ecological Footprint (EF) for urban sustainability assessment based on the model. In addition, we evaluated the effects of policy alternatives on the urban planning using the three sustainability indicators. The results showed that the rapid economic growth and population increase in Shanghai by 2020 would cause 80 percent increases in TMR over 2004, but it could be reduced by 18% through the shift to compact urban form in multi-polar pattern. Also we found that the indirect EF by construction materials production would become a large part of total EF in high urban growth period, but the indirect EF by electricity and food consumption would increase in the period of stable urban growth.

Finally, we developed a framework consisting of several models to estimate the urban energy flow at the city/regional level and of indices to evaluate the sustainability of the urban energy flow. The indices were designed to evaluate the impact on the atmospheric environment, global environment, urban heat island and non-renewable resource consumption as well as the eco-efficiency. Additionally, the energy flow of the residential sector is estimated to evaluate the thermodynamic efficiency of energy consumption, which is applied to find better ways in which energy is consumed. We applied the framework to Osaka city and discussed practicability and weakness of the framework.

5. Scientific outcome
- The basic dataset of the dissemination roadmap of solar water heater, which is more efficient than a solar photovoltaic power generation system was constructed.
- The viewpoint that comparing Japanese consumers, Chinese consumers are more sensitive to monetary incentives is empirically examined.
- The policies undertaken to promote photovoltaic power generation in Japan and Europe and how these policies connected with the development and dissemination of energy-saving technologies were systematically reviewed.
- The energy final demand simulation model for Chinese and Japanese households in consideration of the energy-saving effect, the CO_2 reduction effect, the technological characteristics, and the regional characteristics was developed.
- A case model predicting the dissemination rate of energy-saving technology was developed, which was based on the integration of consumers' preferences on technology, institutional design, and technology characteristics.
- An estimation model for environmental load generated by household sector was developed, which was based on the survey in Shanghai.
- The impact of consumers' lifestyle in and around to Shanghai on the material use and carbon

dioxide emissions was estimated.

- Several designed indices for sustainability of underground resources, land surface resources, and air resources were evaluated based on the scenarios of future changes in Shanghai.

6. Contribution to policy of global environmental issues for decision makers

- The possibility of success in the policy of feed-in tariff in both China and Japan was predicted.
- It was concluded that image strategy is an important factor for the dissemination of solar water heater in Japan and policy of decreasing consumers' initial cost is important for the dissemination of energy-saving machines in China.
- Contribution was made in the sense of being able to rank different policy target setting based on the estimation of energy demand and used home appliances potential in Shanghai's household sector with a consideration of future uncertainty.
- Analysis on the policies for environmental-friendly products based on modeling environmental impact caused by consumers' life style and consumption pattern is identical to the sustainable consumption initiatives promoted by UNEP.
- It was suggested that changing the current urban policy into creating a multipolar pattern city is a good substitution for Shanghai to be a sustainable city through adding the development and dissemination of pro-environmental technology into consideration.
- Providing useful guides for developing applicable sustainability indices based on the evaluation of applying various existed sustainability indices in Shanghai's environmental performance.

References

1) Antweiler, W., B. R. Copeland and M. S. Taylor. Is free trade good for the environment? *American Economic Review*. **91**. 877-908. (2001)

2) Saijo, T. and H. Nakamura. The "spite" dilemma in voluntary contribution mechanism experiments. *Journal of Conflict Resolutio*n. **39**. 535-560. (1995)

3) Van Liere, K. D. and R. E. Dunlap. The social bases of environmental concern: A review of hypotheses, explanations and empirical evidence. *The Public Opinion Quarterly*. **44**. 181-197. (1980)

4) Fransson, N. and T. Gärling. Environmental concern: Conceptual definitions, measurement methods, and research findings. *Journal of Environmental Psychology*. **19**. 369-382. (1999)

5) Bjorner, T. B., L. G. Hansen, and C. R. Russell. Environmental labeling and consumers' choice – an empirical analysis of the effect of the Nordic Swan. *Journal of Environmental Economics and Management*. **47**. 411-434. (2004)

6) Teisl, M. F., B. Roe, and R. L. Hicks. Can eco-labels tune a market? Evidence from dolphin-safe labeling. *Journal of Environmental Economics and Management*. **43**. 339-359. (2002)

7) Loureiro, M. L., J. J. McCluskey, and R. C. Mittelhammer. Will consumers pay a premium for eco-labeled apples?. *Journal of Consumer Affairs*. **36**. 203-219. (2002)

8) Banerjee, A. and B. D. Solomon. Eco-labeling for energy efficiency and sustainability: A meta-evaluation of US programs. *Energy Policy*. **31**. 109-123. (2003)

9) Howarth, R. B, B. M. Haddad, and B. Paton. The economics of energy efficiency: insights from voluntary participation programs. *Energy Policy*. **28**. 477-486. (2000)

Major Publications

1) Saijo, T., J. Shen, X. Qin, and K. Akai: Discussion Paper in Osaka School of International Public Policy (OSIPP). DP-2007-E-004. Osaka University (2007)
   "The spite dilemma revisited: Comparison between Chinese and Japanese"

2) Shen, J. and T. Saijo: Discussion Paper in Osaka School of International Public Policy (OSIPP). DP-2007-E-003. Osaka University (2007)
   "The socioeconomic determinants of individual environmental concern: Evidence from Shanghai data"

3) T. Saijo: Handbook of Experimental Economics Results, Charles R. Plott and Vernon L. Smith (Eds), Elsevier Science, 1,802-816(2008)
   "Spiteful Behavior in Voluntary Contribution Mechanism Experiments"

4) Junyi Shen and Tatsuyoshi Saijo: Journal of Environmental Psychology,28,42-50(2008)
   "Reexamining the relations between socio-demographic characteristics and individual environmental concern: Evidence from Shanghai data"

5) Y. Shimoda, Y. Yamaguchi, C. Kishi, Y. Yamaguchi: Proceedings of the World Sustainable Building Conference 2008, 983-990(2008)
   "Evaluation on sustainability of urban energy system by energy flow analysis"

6) Y. Yamaguchi, Y. Shimoda, A. Taniguchi: Proceedings of the World Sustainable Building Conference 2008, 2521-2528(2008)
   "Evaluation of Energy Saving Measures in Long-term Scenario in Japanese Residential Sector"

7) Shen, J. and T. Saijo: Discussion Paper in Osaka School of International Public Policy (OSIPP), DP-2007-E-005, Osaka University (2008)
   "Does energy efficiency label alter consumers' purchase decision? A latent class approach on Shanghai data"

8) Y.Shimoda, Y. Yamaguchi, T. Okamura, A. Taniguchi, Y. Yamaguchi: Journal of Japan Society of Energy and Resources, 30,3,2009
   "Prediction of Greenhouse Gas Reduction Potential in Japanese Residential Sector by Residential Energy End-Use Model." (in press)