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I am a development economist with a strong interest in econometric issues motivated by empirical work. My research in development has focused on understanding why and how households and firms in poor countries adopt technologies and on measuring their realized benefits in actual field settings. In my econometric work, I have examined problems with mismeasured data and the implications of commonly used computational procedures for the statistical properties of the resultant estimators.

Technology Adoption: Health

One common characterization of developing economies is that certain markets are less likely to exist with important welfare consequences. There is a considerable literature documenting the low demand for technologies despite the fact that they have substantial health benefits. One of the prominent proposed explanations for this is market imperfections such as credit or liquidity constraints. One of the aims of my first research project was to assess the relative importance of this explanation in the context of the adoption of insecticide treated nets (ITNs).

We examined these issues in a large scale experiment in a poor, rural part of eastern India. To test the hypothesis that liquidity or cash-on-hand constraints play an important role in limiting take-up we worked with a micro-finance organization to offer households the opportunity to purchase ITNs and repay using small weekly installments spread out over a year. We compared this intervention to two alternative methods of ITN provision (in addition to a control group). In the first, meant to approximate existing state run public health efforts, eligible households were offered ITNs at no cost. In the second, households were offered the opportunity to purchase ITNs for immediate cash payment.

In Tarozzi, Mahajan, Blackburn, Kopf, Krishnan, and Yoong (2013) (forthcoming *American Economic Review*) we report the main results from the experiment. We find that micro-loans successfully increased ITN ownership and usage. In such villages, 52% of sample households purchased at least one ITN despite a relatively high offer price (ownership was near universal among eligible households in villages where ITNs were distributed at no cost). Among treatment groups, ITN ownership rates were the lowest in villages where ITNs were offered exclusively for cash with only 10% of households purchasing one or more ITNs.

The high uptake using micro-loans contrasts sharply with the low demand for health products documented among poor households in the literature as well as in our cash arm and provides evidence that cash-on-hand constraints may be important in the adoption of health improving technologies. Further, these findings suggest that micro-loans may be a potentially effective tool to increase uptake of health products in poor areas, when free provision is not possible or desirable (although the presence of externalities complicates this

argument as we discuss below).

Measuring Outcomes in Field Settings

An explicit aim of the project was to measure health outcomes carefully in field conditions (as opposed to the highly controlled conditions imposed in public health experiments) as a first stage in formulating the cost-benefit decision for households. We found that increased ITN ownership and usage had mixed effects on health. Malaria prevalence and haemoglobin levels (both measured using blood tests) were the same across all arms. On the other hand, self-reported malaria incidence declined in the treatment arms (even after accounting for the potential measurement error in such self-reports) and the declines were large enough to suggest that ITNs are cost effective for individual households, providing evidence that the liquidity constraints had adverse welfare consequences.

While the ITNs provided some measure of individual protection, the improvements are more modest than those found in many public health experiments. Ultimately, we conjecture that the difference rests on a comparison between our study design, which involved low ITN coverage rates and no monitoring of ITN usage, and the earlier literature which evaluates programs under high coverage rates and/or close monitoring of health and ITN usage. We hypothesize that the increase in ITN ownership and usage rates was not large enough to dent the cycle of malaria transmission which is required to reduce prevalence.[1]

Finally, the limited health benefits also provide a more nuanced approach to the issue of cost recovery. Cost recovery programs (even when relatively cost effective and successful at inducing high uptake of health products, as in our case) for technologies with geographic externalities may limit the ability to reach the critical levels of coverage required for health benefits to arise.

The project also yielded other insights. In Tarozzi, Mahajan, Yoong, and Blackburn (2009) we show that households who had pre-committed to purchase health improving technologies (in this case the insecticide for use with ITNs) were much more likely to do so that households who had not (although we could not experimentally rule out selection effects). In Foo, Mahajan, Tarozzi, Yoong, Krishnan, Kopf, and Blackburn (2011) we document that, contrary to state public health policy, Lympahtic Filariasis was endemic in our study regions and we urged that the state government implement a mass drug administration program in the area. Finally, in Mahajan, Tarozzi, Yoong, and Blackburn (2010) (revise and resubmit at *Quantitative Economics*) we identify and estimate a static model of technology adoption with very weak restrictions on the unobserved heterogeneity component of the model as well

[1] These findings are potentially important because many ITN distribution programs only target vulnerable groups (such as young children and pregnant women) who are typically a small fraction of the population. Such programs may not attain sufficiently high coverage (with their associated externalities) and may therefore provide health benefits that are much lower than one might expect from public health efficacy trials.

as on the utility functions. The results suggest that beliefs — both about the efficacy of ITNs as well as about the usage behavior of neighbors — have an important effect on adoption decisions. The methods proposed in this paper should also have general applicability to other discrete choice models with non-linear indices.

Technology Adoption and Time Inconsistency

Market imperfections are not the only explanation for the observed low demand for health improving technologies in developing countries. Another important category of explanation is preference based — specifically present-biased preferences. Such preferences have recently been invoked to rationalize a range of behaviors such as addiction, preference reversals in intertemporal choices and under-investment in activities with apparent low cost and high expected returns.

Structural estimation of the discount factors that characterize hyperbolic preferences is non-trivial. In fact, time preference parameters are generically not identified even in standard dynamic choice models. The identification of both the standard exponential parameter as well as the additional parameter(s) capturing inconsistency is thus a fundamental problem that has hampered progress in the estimation of these models.

In Mahajan and Tarozzi (2011) (revise and resubmit at *Econometrica*) we provide set and point identification results for dynamic choice models with time-inconsistent agents and unobserved types with general time-varying preferences and type-varying time-preferences. Allowing for unobserved types recognizes that information collected from survey data and field interventions is typically only partially accurate in terms of identifying preferences. Allowing for general variation in preferences across types allows us to test whether agent behavior is better explained by variations in time-preferences or by differences in other preference parameters. The identification results are presented in a general form so that they can be used by researchers in other contexts. In fact, in ongoing work with Damon Jones we apply the identification results from this paper in an empirical application examining time-preference issues around the saving behavior of poor households in New York City.

The original model was estimated using data from the field intervention in India and the fully specified model was then used to evaluate the effects of several different alternative policies. This allows us to learn about counterfactuals for policy interventions that were not part of the original experiment but are nevertheless important from both a theoretical and a policy perspective. For instance, we examined the effect of changes in prices that were not part of the experiment as well as decomposed the sensitivity of the results to the different components of preferences.

Technology Adoption: Management Practices

My second major research project also examines technology adoption but in the context of the manufacturing sector and, like the malaria study, tries to explicitly measure the link between technology adoption and improved outcomes in the field under "real-world" conditions. Economists have long puzzled over the massive differences in productivity across firms and countries with the dispersion appearing particularly pronounced for developing countries. One natural explanation for these productivity differences lies in variations in management practices.

In Bloom, Eifert, Mahajan, McKenzie, and Roberts (2013) we provided the first experimental evidence on the importance of management practices in large firms. The experiment took large, multi-plant Indian textile firms and randomly allocated their plants to treatment and control groups. Treatment plants received five months of extensive management consulting from a large international consulting firm. The treatment intervention led to significant improvements in quality, inventory, and output which were extremely carefully measured and at high frequencies (weekly in most cases) . We estimate that within the first year productivity increased by 17% and, based on these changes, impute that annual profitability increased by about $325,000. These better managed firms also appeared to grow faster, with suggestive evidence that better management allowed them to delegate more and open more production plants in the three years following the start of the experiment. These firms also spread these management improvements from their treatment plants to other plants they owned, providing further revealed preference evidence on their beneficial impact.

Given this large positive impact of modern management, the natural question is why firms had not previously adopted these practices. Our evidence from the initial experiment is that firms were not adopting modern management practices because of a lack of information. In particular, firms faced two informational problems. First, they simply had not heard of many of the modern practices. Second, firms were often skeptical of the impact of modern management practices even if they were aware of them. In addition, the lack of enthusiasm and incentives for middle-managers in these firms also appeared to be a contributing factor towards the non-implementation of modern practices. A further issue is that these improvements in management practices were extremely costly. As a public policy prescription therefore this particular intervention is not scalable. However, most of the consultant introduced improvements were sufficiently straightforward that we believe they could be adopted at a fraction of the cost given the right approach. In a follow-on study, we propose to overcome these informational problems using cost-effective demonstration projects as well as manager incentives.

I have also explored how firms respond to the introduction of institutional innovations in

a historical setting. In Abramitzky, Frank, and Mahajan (2010) we digitized archival data on business partnerships in 19^{th} century Rio de Janeiro to examine how the introduction of institutional innovations that increased investment opportunities and facilitated borrowing affected the terms of the contracts between business partners. We find that the institutional innovations improved terms for partners with unlimited liability in a manner consistent with an increase in their bargaining power.

In addition to my substantive interests in development, my research agenda also includes work in econometric theory and I outline two such projects. It is worth emphasizing that I see myself primarily as a development economist with the bulk of my ongoing research projects being in that field. At the same time, I plan to continue to work on econometric problems of interest that may arise in my empirical work. At this point, I hope to have one active econometric project at any given point in time with the remaining projects being in development.

Mismeasured Data

Measurement error is pervasive in empirical work. Past approaches to dealing with it have usually assumed that such errors are classical in nature and have then applied standard correction methods. However, evidence suggests that measurement error in economic data is usually not classical in nature.

In Mahajan (2009) I propose a method that allows researchers to estimate demand responses in a flexible manner while at the same time accounting for the non-classical nature of the measurement error in reported prices. This done by modeling the form of the non-classical measurement error and recovering the distribution of interest by solving a recursive system of equations. I develop the theoretical results required and apply the method to estimate the price elasticity for wheat, a staple commodity, in western India. The results suggest that there is considerable variation in price elasticities along the price distribution, something missed in previous work using linear demand specifications.

This paper proposed a parametric correction for the measurement error problem for a specific application. However, this solution is not entirely satisfactory and I explore more general approaches in Mahajan (2006).[2] I develop a theoretical framework to first characterize the limits to knowledge of regression parameters when measurement error depends upon observable characteristics of respondents, and second, to discuss alternative methods of identifying these models when further information is available. The results highlight the critical nature of the independence assumption in classical error models and provide an alternative set of assumptions to achieve identification. I also propose a new estimation scheme based on the identification results. The results here, with application specific modifications, are

[2]Though published earlier, this paper was motivated by and written after the previous one.

currently in the process of being applied in empirical contexts by other researchers.

The Statistical Implications of Numerical Differentiation

The estimation of non-linear and/or non-smooth objective functions is common in empirical microeconomic work. Such estimation often involves the use of numerical optimization and approximation routines. In joint work, we are currently exploring the consequences of this approximation for the statistical properties of the resulting estimators.

In Hong, Mahajan, and Nekipelov (2012a) (revise and resubmit *Journal of Econometrics*) we find that the step-size involved in the finite-difference approximation plays an important role in the large sample properties of the resulting estimators (in a manner akin to the choice of bandwidth choice in kernel based estimation procedures). We provide weak sufficient conditions for the uniform consistency of the finite-difference approximations for gradients and directional derivatives. We then show that the asymptotic distribution of the resulting estimators can depend upon the underlying sequence of step-size choices and state conditions under which the numerical derivative based estimator is consistent and asymptotically normal. We also generalize our results to semi-parametric estimation problems and show that our results are useful for a variety of non-standard estimation problems. In Hong, Mahajan, and Nekipelov (2012b) (revise and resubmit *Econometric Theory*) we investigate the effect of finite-difference based derivative approximations on estimators based on objective functions defined via U-statistics, particularly those with non-smooth kernels. Our current findings indicate that the previous guides in the literature for the choice of step-size were conservative and we provide improved rates. These results should allow researchers to use U-statistic based approaches with non-smooth objective functions particularly in situations with large data sets, which is becoming increasingly common.

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