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Can Robbery and Other Theft Help Explain the Textbook Currency-demand Puzzle? Two Dreadful Models of Money Demand with an Endogenous Probability of Crime

by

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ABSTRACT

This paper attempts to explain one version of an empirical puzzle noted by Mankiw (2003): a Baumol-Tobin inventory-theoretic money demand equation predicts that the average U.S. adult should have held approximately $551.05 in currency and coin in 1995, while data show an average of $100. The models in this paper help explain this discrepancy using two assumptions: (1) the probabilities of being robbed or pick-pocketed, or having a purse snatched, depend on the amount of cash held; and (2) there are costs of being robbed other than loss of cash, such as injury, medical bills, lost time at work, and trauma. Two models are presented: a dynamic, stochastic model with both instantaneous and decaying noncash costs of robbery, and a revised version of the inventory-theoretic model that includes one-period noncash costs. The former model yields an easily interpreted first-order condition for money demand involving various marginal costs and benefits of holding cash. The latter model gives quantitative solutions for money demand that come much closer to matching the 1995 data—$75.98 for one plausible set of parameters. This figure implies that consumers held approximately $96 billion less cash in May 1995 than they would have in a world without crime. The modified Baumol-Tobin model predicts a large increase in household money demand in 2005, mostly due to reduced crime rates.

Keywords: Currency Demand; Crime; Baumol-Tobin; Dynamic Programming

JEL Classifications: E410, D110, D900

"A man carrying a bag filled with nearly $150,000 in cash that he had just withdrawn from a bank in Midtown Manhattan was assaulted and robbed by an armed man on Friday afternoon, officials said. . . .One witness said the attacker repeatedly struck the man, and then dragged him several feet along the sidewalk in an apparent struggle over a black duffel bag that the police said was filled with cash. . . .Detectives are investigating whether the assailant knew that the man would be making a large withdrawal, or whether the attacker just happened to notice him taking out the money and moved in on him, the police said."

New York Times, February 23, 2008 (Baker 2008)

1. INTRODUCTION

It is likely that this man had some reason for withdrawing such a large amount of money, but how rational are the rest of us? Few studies have been done on actual balances of currency. Porter and Judson (1996), citing a Federal Reserve survey of 500 households in 1995, report that the average U.S. adult held $100 in cash ($136 in 2007 dollars).

A problem in N. Gregory Mankiw's intermediate macroeconomics text points out that a Baumol-Tobin model of money demand suggests that this amount is much too small (Mankiw 2003, p. 449; Baumol 1952; Tobin 1956). The Baumol-Tobin model involves maximizing the following function, which gives the total costs of holding average money balances, M

$$-iM - \frac{C(wh + f)}{2M}$$

where i is the nominal interest rate, representing the opportunity cost of holding cash, C is the amount of consumption paid for with cash, w is the nominal hourly wage or value of time, h is the amount of time (measured in hours) required for a trip to the bank or automatic teller machine (ATM), and f is the monetary cost of a withdrawal (such as an ATM fee). Maximizing this function with respect to M gives the first-order condition

$$0 = -i + \frac{C(wh + f)}{2M^2}$$

Using the May 1995 one-month CD rate of 5.98 percent, a measure of per capita nondurable consumption likely to be paid for with cash, the wage for private-sector production workers, a time cost for a trip to the bank of ten minutes, and an ATM fee of one dollar, the model gives a cash demand of $551.05[1] (See Appendix 2 for details about the data used in these calculations). And this model does not take into account the possible need for precautionary balances. What accounts for this discrepancy?

Another problem in Mankiw's text looks at the possibility that the chance of loss or theft might decrease desired balances. A simple way of doing so would be to use the objective function

$$-iM - \frac{C(wh + f)}{2M} - P\,M$$

where P is the probability that the agent's cash will be lost or stolen. Data from the National Crime Victimization Survey (CVS), conducted by the U.S. Department of Justice (Bureau of Justice Statistics 1997), indicate that the incidence of completed robbery in 1995 was 3.5 per thousand persons age 12 or over.[2] The incidence of personal theft (meaning pick-pocketing or purse-snatching) was 1.9 per thousand. Adding these two figures gives P = .0035 + .0019 = .0054. Using this figure in the equation above gives a money demand of $527.73, still far above the Federal Reserve survey result. To take into account losses unrelated to crime, a larger P might be appropriate. Increasing P to .01 lowers the amount to $510.05—a figure that still strikes most people as far too high.

But it is not clear that P itself is independent of the amount of money a person holds. A common phrase on crime-prevention and tourist-advice websites is "Don't flash

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[1] This figure is very high relative to weekly earnings. It may be doubtful that a worker without direct deposit would, on average, carry an amount of cash larger than his or her paycheck, since depositing the check in person requires a trip to the bank. Also, many people live "paycheck to paycheck." For example, a full-time worker receiving the average wage used in this model for 1995 would have a gross biweekly paycheck of $926.40. If he or she always spends this entire amount, net of deductions, before the next check arrives, average cash balances could not be as described by this model. (The median and average U.S. residents have significant real wealth, however.)

[2] Robbery is a type of theft in which the robber directly confronts the victim and uses, or threatens to use, force, with or without a weapon. Pick-pocketing and purse-snatching do not involve the use of force, but in these crimes, the thief also steals items directly from a person, rather than from an unoccupied house, office, car, etc. See footnotes to Table 2 for sources.

your cash!" meaning, "Don't openly handle large amounts of money!" Perhaps people carry less cash than theory predicts because potential thieves would be more likely to commit a crime if larger amounts of cash were at stake. Some empirical evidence for this idea exists (Porter and Judson 1996, p. 902; Rogoff, Giavazzi, and Schneider 1998, p. 278; but see Jankowski, Porter, and Rice 2007).

This paper pursues a twofold explanation of low household demand for cash based on this idea. First, the probability of being robbed or being the victim of a purse-snatcher or pick-pocket depends on the amount of money one holds—an endogenous probability of crime. Second, the costs of being robbed include not only the loss of the stolen money, but also what I will call "noncash" or nonpecuniary costs: psychological trauma, physical injury, lost time at work, medical bills, etc. I find that this model can go a long way toward explaining why individuals hold so much less money than theory would suggest.

The paper has five sections. Section 2 sketches some background facts about money holdings, theft, and robbery and reviews certain literature. Section 3 presents a dynamic money-in-the-utility-function model with nonpecuniary costs of robbery, some of which are incurred immediately and some of which decay over time. In this model, the probability of robbery is a function of the amount of money held. The first-order conditions for the solution of the model admit an easy interpretation involving various costs and benefits of holding cash. Section 4 augments the Baumol-Tobin model above with one-period nonpecuniary costs of robbery and endogenous probabilities of robbery, purse-snatching, and pick-pocketing. The latter model is used to arrive at quantitative solutions for money demand that better match the data mentioned above. Section 5 is a conclusion and discusses several implications of the results.

2. SOME BACKGROUND FACTS AND LITERATURE ON CASH HOLDINGS, ROBBERY, AND PERSONAL THEFT

As noted in the previous section, data on household cash (currency and coin) holdings are sparse. One would suspect since debit cards have become more widespread since 1995, cash holdings have fallen since then. Indeed, Humphrey (2004) estimates that 20 percent of the dollar value of consumer transactions was accounted for by cash payments in 2000, down from 22 percent in 1995. While U.S. citizens may use less cash than they have in the past, there has been an influx of Latin American immigrants since the early 1980s, and there is some local evidence that these immigrants tend to use relatively large amounts of cash, especially $100 bills (Jankowski, Porter, and Rice 2007).[3]

An alternative approach is to use aggregate data. Dividing the Federal Reserve's estimate of currency outside financial institutions in September 2007 ($756.8 billion) by the U.S. population of approximately 301 million gives an average balance of $2,509.11, but a great deal of empirical evidence has been adduced that much, or perhaps most, of this amount is held overseas or in the underground economy (Porter and Judson 1996; Rogoff, Giavazzi, and Schneider 1998; Sprenkle 1993). For Icelandic currency, which is probably less commonly used than the dollar in foreign countries, the total stock divided by the population was the equivalent of $281 in 1996 (Rogoff, Giavazzi, and Schneider 1998, p. 275). Lippi and Secchi (2004), using household survey data, estimate that the average Italian household held 376 euros, or about $332, in cash in 2002. The average ATM withdrawal in the United States was $99 in 2006, up from $85 in 2003 (Federal Reserve 2007).

As noted in the introduction, there is some scattered cross-country evidence of a negative effect of violent crime on household cash holdings (Porter and Judson 1996, p. 902; Rogoff, Giavazzi, and Schneider 1998, p. 278). The incidence rates of robbery and theft of personal property were lower in 1991 in Italy than in the United States[4] (International Crime Victims Survey 1997), which might suggest a partial explanation of Lippi and Secchi's findings of higher cash balances in Italy.[5]

A link between black market activity and currency demand equations is not new (Cagan 1958), but there have been few or no theoretical attempts to incorporate robbery and other forms of theft into models of money demand. None are mentioned in surveys of the field or standard references on money demand (Duca and VanHoose 2004; Laidler

[3] The authors note several reasons for the use of cash by immigrants, including distrust of financial institutions, payment of wages in cash when workers are undocumented, and the use of cash for remittances.

[4] The incidence of robbery was 1.5 percent in the United States and 1.3 percent in Italy in 1991. According to the ICVS (1997), 5.3 percent of U.S. residents and 3.6 percent of residents of Italy had personal property stolen that year.

[5] Another might be the large numbers of small shops in Italy that do not accept credit or debit cards.

1977; Judd and Scadding 1982; Serletis 2001). The idea of an endogenous probability of stealing seems obvious and some of those who have mentioned a link between crime and money demand have this idea in mind, along with black market use of cash, which has the opposite effect (e.g., Jankowski, Porter, and Rice 2007, p. 18, footnote). Economists have studied the demand for goods that reduce the probability of crime for many years (e.g., Clotfelter 1977).

A few pieces of information from the National Crime Victimization Survey (Bureau of Justice Statistics 2006b) on robbery and other forms of theft seem relevant here. The national crime victimization survey reports that there were 624,850 robberies in the United States in 2005 (see Table 1). This amounts to a rate of 2.6 robberies per 1000 people over 12. The rate for female victims was 1.4 per thousand; for male victims, 3.8 per thousand. (These numbers were much higher, as discussed below, in 1995, the year of the Fed cash-balance study. See Table 2.) The 16-to-19 age group was the most vulnerable to robbery. The lower a person's family income, the more likely they were to be robbed, with a remarkable .56 percent of those with family incomes of less than $7,500 falling victim to a robbery in 2005. There were 43,550 instances of purse-snatching and 173,980 cases of pick-pocketing, for a total victimization rate of .9 per thousand people.

Of all robberies, 20.1 percent were committed by someone whom the victim knew. Female robbery victims were much more likely than males to have been robbed by someone they knew. Robbers used weapons in 51.3 percent of successful robberies and 42.2 percent of unsuccessful robberies.

For robbery, the median property loss was $120 and the average was $791. The median loss for purse-snatching was $110 and for pick-pocketing the median loss was $62. The median losses for men and women and for whites and blacks were similar. The main property lost in robberies was cash or a purse, wallet, or credit cards in 55.3 percent of cases. The corresponding figure for pick-pocketing and purse-snatching was 87.8 percent. When a person's pocket was picked or purse stolen, the lost property was fully recovered only 6.7 percent of the time, while property was fully recovered after 14.7 percent of robberies. After a robbery or attempted robbery, 10.2 percent of victims missed time from work. Victims sustained injuries in 33.2 percent of all robberies. The percentage of male victims injured was slightly higher than the percentage of female victims injured. After 11.3 percent of robberies, victims incurred medical expenses.

Of course, many additional data sources are available. A Swedish study found that robbery was a strong predictor of post-traumatic stress syndrome (Frans, Rimmö, Åberg, and Frederikson 2005). The International Crime Victims Survey (ICVS) found larger incidence rates for robbery (12 per thousand people aged 16 or above) and pick-pocketing (8 per thousand) in their 2000 study, the last one for which published data are available (Van Kesteren, Mayhew, and Nieuwbeerta 2000) (see Table 1). Like the national survey, it revealed higher rates for both crimes in 1995 than more recently (see Table 2).

3. A DYNAMIC MONETARY MODEL WITH NONCASH COSTS AND AN ENDOGENOUS PROBABILITY OF ROBBERY

In one standard type of intertemporal monetary model, the demand for money is generated by assuming that higher real balances allow the consumer to spend less time traveling to the bank, increasing time available for work or leisure. I will use an equivalent formulation in the tradition of Sidrauski (1967), in which the consumer directly receives utility from real balances. Furthermore, it seems appropriate to measure the costs of being robbed. These can include the psychological impact, the effects of any injuries during the robbery, and so on. Moreover, these effects carry over into future periods by contributing to a state variable that might be called “the stock of trauma.” The model contains only two financial assets, bonds and currency, but could easily be extended to include others, including checking accounts.

The utility function of the representative consumer is

$$\sum_{t=0}^{\infty}\beta^t E(U(M_t/P_{t-1},C_t,R_t))=\sum_{t=0}^{\infty}\beta^t(u(M_t/P_{t-1},C_t)-P(M_t/P_{t-1})w(M_t/P_{t-1})-g(R_t)) \quad (1)$$

where $0<\beta<1$ is the discount factor; M_t is nominal holdings in period t of currency; C_t is the amount of the consumption good consumed; P_t is the period t price level of that good;

$0 < P(M_t/P_{t-1}) < 1$ is the probability of being robbed, conditional on the amount of real balances, M_t/P_{t-1}; and R_t is the amount of "trauma" from past robberies. This model does not include forms of theft other than robbery, which probably cause less trauma and injury. I will assume that real balances are bounded above. The functions u, w, and g are twice continuously differentiable, with

$$u_1 > 0; u_2 > 0; u_{11} < 0; u_{22} < 0; P' > 0; P'' > 0; w' > 0; w'' > 0; g' > 0; g'' > 0$$

The function u is strictly concave and bounded above and is a standard utility function of the type used in Sidrauski models; w is the nonpecuniary disutility of being robbed, which is assumed to depend on the amount of cash lost; and g is the impact of past robberies on utility, due to trauma, injury, and so on. The functions u, w, and g are specified so that the expression in (1) is always nonnegative.

The constraint and law of motion for the problem depend upon whether the consumer is robbed of his or her cash balances. When the consumer is robbed of his or her cash, his or her financial constraint is

$$A_{t+1} = (1+r)B_t = (1+r)(A_t - C_t - M_t / P_{t-1} + y) \equiv A_{t+1}' \tag{2}$$

where A_t is financial assets in period t, r is the real interest rate, B_t is the number of bonds (with assets and bonds denominated in units of the consumption good), and y is the consumer's endowment, which is the same in each period. The consumer receives interest on the amount of the previous period that he or she invested in bonds (i.e., did not consume or change into cash).

Since I will not be focusing on intertemporal consumption decisions, I will assume for simplicity that

$$\beta = (1+r)^{-1}$$

When the consumer is not robbed and thus retains his or her cash balances from the previous period, which nonetheless may be eroded by inflation

$$A_{t+1} = (1+r)B_t + M_t / P_t = (1+r)(A_t - C_t - M_t / P_{t-1} + y) + M_t / P_t \equiv A_{t+1}'' \qquad (3)$$

Assets are allowed to become negative, but must remain greater than or equal to some lower bound B, meaning that the consumer can borrow by "issuing bonds," but has a credit limit.

The law of motion of the stock of trauma from robbery is

$$R_{t+1} = \alpha R_t + 1 \equiv R_{t+1}' \qquad (4)$$

if the consumer is robbed, where

$$0 < \alpha < 1$$

and

$$R_{t+1} = \alpha R_t \equiv R_{t+1}'' \qquad (5)$$

if the consumer is not robbed. Trauma fades away with time, but increases any time a robbery occurs.

I will use the exogenous shock variable Z_t to indicate whether the consumer was robbed in period t, which will take on the value 1 if a robbery has taken place and zero if not. The set

$$Z^t = \{Z_1, Z_2, Z_3, ..., Z_t)$$

is the history of this exogenous state variable, which takes on the value 1 with the probability P each period. The consumer's problem is to maximize (1), subject to (2), (3), (4), and (5).

Specifically, the consumer's problem is to choose a *plan*

$$\Pi = \{\Pi_1, \Pi_2, \Pi_3, ...\}$$

where Π_t is a vector-valued function mapping the state variables onto the real plane

$$(M_t,\, C_t) = \Pi_t(Z^{t-1})$$

Of course, I will restrict my attention to plans that are *feasible*, meaning that they obey the constraints (2) and (3), given the history of victimizations Z^t.

The Bellman equation for the problem is

$$V(A_t, R_t) = \sup_{C_t,\, M_t} \{u(M_t / P_{t-1}, C_t) - P(M_t / P_{t-1}) w(M_t / P_{t-1}) - g(R_t) + \beta E(V(A_{t+1}, R_{t+1}) \mid M_t / P_{t-1})\} \tag{6}$$

where

$$E(V(A_{t+1}, R_{t+1}) \mid M_t / P_{t-1}) = P(M_t / P_{t-1}) V((1+r)(A_t - C_t + y - M_t / P_{t-1}), \alpha R_t + 1)) +$$
$$(1 - P(M_t / P_{t-1})) V((1+r)(A_t - C_t + y - M_t / P_{t-1}) + M_t / P_t,\, \alpha R_t)$$

and the supremum is over sequences that obey a no-Ponzi condition, the credit limit, nonnegativity constraints on M_t and C_t, and the upper bound on M_t/P_{t-1}. By Blackwell's sufficient conditions (Stokey and Lucas 1989, p. 54), the right hand side of equation (6) is a contraction in the space of bounded, nonnegative, continuous functions V on pairs of nonnegative numbers with the sup norm. Hence it has a solution V in that space.

Moreover, V is strictly concave and continuously differentiable. The supreme value function satisfies (6) (see Appendix 1 for details).

The Bellman equation (6) is sufficient to ensure that V is equal to the supreme value function, and all plans generated $\Pi_t^*(Z^{t-1})$ by the Bellman function as follows

$$\Pi_t^*(z^{t-1}) = \underset{C_t,\, M_t}{\arg\max}\{u(M_t/P_{t-1}, C_t) - P(M_t/P_{t-1})w(M_t/P_{t-1}) - g(R_t) + \beta E(V(A_{t+1}, R_{t+1}) \mid M_t/P_{t-1})\} \tag{7}$$

achieve the supremum (see appendix for details).

Because of the continuity of the expression inside the brackets and the compactness of the action space, we can be sure that there is such a plan. By strict concavity, that plan is unique.

The first-order necessary and sufficient conditions for an interior maximum for the problem on the right-hand side of (6) are

$$u_2(M_t/P_{t-1}, C_t) = P(M_t/P_{t-1})V_1(A_{t+1}', R_{t+1}') + (1 - P(M_t/P_{t-1}))V_1(A_{t+1}'', R_{t+1}'') \tag{8}$$

$$\begin{aligned} 0 = {} & u_1(M_t/P_{t-1}, C_t) - pw'(M_t/P_{t-1}) + \beta(P'(M_t/P_{t-1})(V(A_{t+1}', R_{t+1}') - V(A_{t+1}'', R_{t+1}'')) \\ & - P(M_t/P_{t-1})V_1(A_{t+1}', R_{t+1}')(1+r) + (1 - P(M_t/P_{t-1}))V_1(A_{t+1}'', R_{t+1}'')(1/\Pi_t - (1+r))) \end{aligned} \tag{9}$$

where numerical subscripts on functions indicate partial differentiation by the relevant variable, $\Pi_t = P_t/P_{t-1}$, and, for compactness of notation, the function pw' is used to denote the partial derivative of $P(M_t/P_{t-1})w(M_t/P_{t-1})$ with respect to real balances.

The envelope theorem implies that the following holds in the interior of the choice set

$$V_1(A_t, R_t) = u_2(M_t/P_{t-1}, C_t) \tag{10}$$

The Euler and money demand equations are

$$u_2(M_t/P_{t-1}, C_t) = P(M_t/P_{t-1})u_2((M_{t+1}/P_t)', C_{t+1}') + (1 - P(M_t/P_{t-1}))u_2((M_{t+1}/P_t)'', C_{t+1}'') \tag{11}$$

$$\begin{aligned} 0 = {} & u_1(M_t/P_{t-1}, C_t) - pw'(M_t/P_{t-1}) + \beta(P'(M_t/P_{t-1})(V(A_{t+1}', R_{t+1}') - V(A_{t+1}'', R_{t+1}'')) \\ & - P(M_t/P_{t-1})(1+r)u_2((M_{t+1}/P_t)', C_{t+1}') + (1 - P(M_t/P_{t-1}))(1/\Pi_t - (1+r))(u_2((M_{t+1}/P_t)'', C_{t+1}'')) \end{aligned} \tag{12}$$

where (M_{t+1}/P_t)' and C_{t+1}' are next period's real balances and consumption in the event that I am robbed in this period, and the corresponding variables with double-prime marks are those planned in the event of no robbery. Equation 11 can be found by combining (8) and (10), and (12) can be derived from (9) and (10).

The Euler equation (11) is standard in problems of this type. Condition (12) shows that the consumer chooses monetary balances by weighing the following marginal benefits and costs of holding an additional unit of cash:

(1) the first term is the standard marginal utility benefit due to a reduction in "shoe-leather costs," etc.;

(2) the second term is the joint effect of higher balances on both the probability of being robbed and the severity of the nonpecuniary effects of being robbed;

(3) the next term, involving the difference between the values of V in the cases of robbery and no robbery, shows the marginal impact of a higher probability of being robbed on the expected stocks of assets, A_{t+1} and trauma, R_{t+1} and hence on future utility (note that this term is negative because the value function is strictly increasing in assets and strictly decreasing in the stock of trauma); and

(4) the last two terms represent the marginal utility costs due to foregone consumption in period t+1 (at a given probability of robbery). First, in the case of robbery with probability P, the consumer loses the gross return (1+r) that he or she would have earned by storing a marginal unit of wealth in bonds; second, if no robbery occurs, an event with probability (1-P), the consumer still loses the gross bond return, but retains the money, which is scaled down by inflation to obtain new real balances.

Hence, there are four reasons in this model why the possibility of being robbed reduces the net marginal benefits of holding real balances. First, any case of robbery reduces psychological and/or physical well-being. This is due to (a) the impact on current-period utility, through the function w and (b) the impact on future utility, through the function g. The expected value of both of these costs is increased when more money is held, because the consumer is more likely to be robbed when he or she is holding more real balances and because robbery creates more immediate disutility when more money is lost. Second, the consumer also loses utility when he or she is robbed because of a loss of cash to the robber. This loss (c) has a higher probability and (d) is larger, when more real balances are held.

4. HOW MUCH DOES CRIME AVOIDANCE EXPLAIN? QUANTIFYING THE EFFECTS OF ENDOGENOUS ROBBERY, PICK-POCKETING, AND PURSE-SNATCHING PROBABILITIES ON MONEY DEMAND

As we saw in the introduction, common sense and the data suggest that people hold very little cash—an average of $100 in 1995 (Porter and Judson 1996). However, I showed that a simple Baumol-Tobin money demand model, which takes into account the financial and time costs of bank transactions, as well as foregone interest due to cash holdings, indicates that each adult should have held approximately $551.05. Mankiw, in his textbook, clearly indicates that the possibility of robbery, theft, or loss could account for part of the puzzle. He clearly believes that these factors are not sufficient to explain the puzzle. In this section, I add the psychological, physical, and other noncash costs of robbery. The use of an endogenous probability of robbery will increase the impact on money demand of expected cash loss due to robbery and make the noncash impact of robbery relevant for a calculation of money demand.

The modified Baumol-Tobin model uses the following objective function

$$-iM - \frac{C(wh + f)}{2M} - P_1(M)M - P_2(M)s \tag{13}$$

The consumer's problem is to maximize this function with respect to the variable M, which represents average nominal currency holdings (the price level is normalized to one). The first two terms are identical to the Baumol-Tobin objective function in the introduction. The third term is the expected amount of money lost to criminals, which equals the average amount of money held, M, times the probability $P_1(M)$ of losing money to robbery, pick-pocketing, or purse-snatching, conditional on the amount of money held. The fourth term is the expected loss above and beyond the amount of cash on hand, which is equal to the conditional probability $P_2(M)$ of an attempted or completed robbery, times the noncash costs of robbery, s.[6]

Maximizing (13) with respect to M gives the following money-demand first-order condition

$$0 = -i + \frac{C(wh+f)}{2M^2} - P_1'(M)M - P_1(M) - P_2'(M)s \tag{14}$$

This equation requires a specification of the conditional probability of loss functions, P_1 and P_2. I will use the logit functions

$$P_1(M) = \frac{\exp(\lambda M + \theta)}{1 + \exp(\lambda M + \theta)} \tag{15}$$

$$P_2(M) = \frac{\exp(\gamma M + \omega)}{1 + \exp(\gamma M + \omega)} \tag{16}$$

where the Greek letters are parameters.[7] These equations give the parameterized demand equation

$$0 = -i + \frac{C(wh+f)}{2M^2} - \frac{Ma\exp(\lambda M + \theta)}{(1 + \exp(\lambda M + \theta))^2} - \frac{\exp(\lambda M + \theta)}{1 + \exp(\lambda M + \theta)} - \frac{sc\exp(\gamma M + \omega)}{(1 + \exp(\gamma M + \omega))^2} \tag{14'}$$

after differentiating (15) and (16) and substituting them into (14). I explain in Appendix 2 how the first two terms are parameterized. I parameterize the rest of (14') as follows.

[6] I ignore burglary and other forms of theft other than robbery, pick-pocketing, and purse-snatching.
[7] This function is convex when the probability P is less than .5. For reasonable values of the parameters, there are no equilibria in the concave part of the function.

I use two logit equations to solve for λ and θ

$$\log\left(\frac{P_1(M')}{1-P_1(M')}\right)=\lambda M'+\theta$$

$$\log\left(\frac{P_1(M'')}{1-P_1(M'')}\right)=\lambda M''+\theta \tag{17}$$

which are obtained after plugging M' and M'' (two different values for M) into (15). For M', I use Porter and Judson's figure of $100 for average cash holdings in May of 1995. For P_1(M'), I use the incidence of completed robbery plus the probability of personal theft (pick-pocketing or purse-snatching) for 1995 from the National Crime Victimization Survey, for a total of .0054 (U.S. Department of Justice 1997).[8] (See Table 2 for 1995 crime rate estimates.)

M" and P_1(M") are counterfactual data points, so I have no data. I will simply explore the implications of certain plausible figures. So, suppose that increasing money holdings to M" = $1,000 (a tenfold increase) would raise the probability of completed robbery or personal theft to P_1(M") = .00594, which is a ten-percent increase. This implies an elasticity[9] of theft to money holdings of approximately .0111. Solving equations (17) with these numbers gives λ = 0.000106504 and θ = -5.22659 (Later I report the implications of other values for the elasticity).

For γ and ω, I use a similar calculation. For P_2(M'), I use the probability of robbery (completed or not completed) from the same survey. M' is again $100. M" and P_2(M") are once again calculated with an assumed elasticity of .0111. For 1995, the probabilities happen to be the same as in the previous calculation, which means that λ = γ and θ = ω.

I also calculate λ, θ, γ, and ω in other ways. For use in my solution of the model for 2004–05, I inflate M' and M" by the increase in the CPI for all urban consumers

[8] The CVS figure for pick-pocketing and purse-snatching includes some unsuccessful attempts to steal purses, resulting in a slight overestimate.
[9] Of course, this number is not truly an elasticity because it is not local. The properties of the function differ for smaller changes in money holdings.

before solving equations (17) and the equivalent equations for γ and ω. I also calculate the corresponding four parameters for 1995 ICVS data.

The costs of victimization are inherently difficult to measure.[10] I explore two possible values for s, the costs of robbery. First, Cohen et al. (2004) used the contingent valuation (willingness-to-pay) method to find the value of a statistical armed robbery of some person in a survey respondent's community.[11] They do not provide a figure for robberies in general. Since this is a cost for a statistical armed robbery of *some* community member, it is surely a lower bound for the cost of a statistical armed robbery to the respondent him or herself. I would surely pay at least as much to prevent a statistical robbery of myself as to stop a statistical robbery of a random member of my community. Cohen et al. (2004) find this cost to be $232,000 in year 2000 dollars ($279,346 in 2007 dollars) for a sample of 798 U.S. respondents.[12]

As a second value for s, I use a figure from Miller, Cohen, and Wiersema (1996), as reported by Cohen (2001, Table 1.1). They construct values from actual damages awarded to crime victims in suits against third parties (for example, the owner of a poorly lit parking lot where an assault took place). They include costs that are imposed on society at large (such as police services) and property loss, which I am counting separately, so I add only the remaining components of the damages they report for actual or attempted robbery: productivity ($950) and quality of life ($5,700), for a total of $6,650 (or about $9,542 in 2007 dollars). (Conservatively, I assume medical and mental health care are paid for by other parties.) These figures do not include punitive damages.

[10] The use of a monetary cost here is not to make an accounting of the worth of crime reduction to society. In this paper, s is used as a measure of willingness to pay to avoid a crime, without any normative implication that a victim would be fairly compensated by a payment of that amount. Some may feel that the costs of robbery are large but reject the notion that they should adjust their behavior in fear. All of these issues are beyond the scope of a model such as the one in this paper.

[11] The term *statistical robbery* implies a marginal reduction in the probability of robbery. So, as a hypothetical example, a value of $232,000 for a statistical robbery does not imply that subjects would be willing (or able) to pay $232,000 for a police car that would prevent a sure robbery in their communities, but they would be willing to contribute $2.32 toward buying a police car that would reduce the probability of robbery from .0054 to .00539. Cohen et al. (2004, p. 94) actually asked subjects about measures that "successfully prevent[] one in ten armed robberies in your community."

[12] Both figures for the nonpecuniary costs of robbery are adjusted to the relevant years using the CPI for all urban consumers. See Appendix 2 for details. Use of the $232,000 figure results in some double-counting, as it presumably includes cash losses, which are accounted for separately in the model. However, the average cash losses incurred in a robbery are obviously only a small fraction of this amount, so double-counting does not affect estimated money demand very much.

With these parameters in hand, I numerically solved (14').[13] The results are shown in Tables 3 and 4 for a number of different sets of parameters, together with the results reported earlier for the model without robbery and other forms of theft. Table 3 shows estimates based on crime rates from the CVS and Table 4 reports estimates derived from ICVS data.

The last row of each table repeats the result reported in Section 1 for a Baumol-Tobin model with no crime. As for the rest of the tables, the first column of each table gives three different noncash costs of robbery: zero; Cohen's (2001) tort-based estimate of $6,650 in 1993 dollars; and the contingent valuation estimate in Cohen et al. (2004), which was $232,000 in 2000 dollars. The second column of the table is for the situation described earlier, in which carrying $1,000 instead of $100 raises the probability of robbery or other theft by 10 percent. The third and fourth columns are for sets of parameters derived under the assumptions that increasing cash holdings from $100 to $500 or $200 raises the probability of crimes by 10 percent, resulting in elasticities of .025 or .1.[14]

The tables show that the model goes a long way toward solving the problem posed by Mankiw in his textbook. The top row of results, for a zero nonpecuniary cost of robbery, shows that an endogenous probability of robbery makes little difference if the representative agent is concerned only about losing his or her cash. The next two rows show much larger reductions in money demand. The estimates based on Cohen et al. (2004) seem most relevant, because they are estimates of willingness to pay to avoid a crime, rather than damage awards in lawsuits against defendants who did not actually commit the crime. Using figures from Cohen et al. for the noncash costs of robbery, Table 3 shows cash demands ranging from $312.90 for a relatively low elasticity of crime to cash balances and $231.79 for a higher elasticity, to $125.78 for the highest elasticity considered.[15] Using the higher crime rates reported in the ICVS, one finds a cash demand

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[13] I used the FindRoot function in Mathematica.
[14] The $500 and $1000 figures were arbitrarily chosen "for the sake of argument" to represent very conservative assumptions about the effect of money holdings on crime. Later, an assumption of $200 was added on the grounds that the original assumptions generated excessive money demands. No attempt was made to adjust the parameters to fit the data exactly.
[15] Evaluating the logit equations (16 and 17) for crime probabilities at the money demand levels reported below give probabilities that are close to their observed levels. Thus, the conditional expectations in the model are fairly consistent with the behavior generated by the model.

of $203.81 with a low elasticity, $143.94 when using a medium elasticity, and $75.98 for a high elasticity. If it is true that the value found by Cohen et al. (2004) is only a lower bound, with actual noncash costs of robbery being much higher, then these numbers would be overestimates. Moreover, this figure is for *armed* robbery. On the other hand, Cohen's (2001) lawsuit-based cost estimates give much weaker results: $509.58, $487.86, and $393.57 for various elasticities and CVS crime rate data with corresponding figures of $427.95, $392.72, and $284.30 for ICVS data. All of these figures compare with the Fed's empirical estimate of $100 and a benchmark Baumol-Tobin demand of $551.05.

How much difference do these estimates make for aggregate cash demand? Multiplying the solution with the best fit [for a high elasticity, ICVS data, and noncash costs of robbery from Cohen et al. (2004)] by the population over age 15 gives $15.09 billion, as opposed to $111.05 billion for a model without crime and Federal Reserve aggregate currency of $367.9 billion.[16] Hence, according to the model, the fear of crime reduced cash demand by 86 percent, or $96.0 billion. This impact is equivalent to 26.1 percent of total currency as measured by the Federal Reserve. Using Porter and Judson's (1996, p. 895) point estimate that 55 percent of all currency is held abroad, eliminating the fear of crime would increase household cash demand by an amount equivalent to 47.5 percent of domestically held currency. The model does not account for hoards, money held by businesses, or precautionary balances, all of which, along with black market demand and foreign holdings, may contribute to the underestimate of domestic currency.

Since I have no recent data on cash holdings, it is not possible to determine if the model performs well when the lower crime rates of today are used to calibrate the model. Still, I will report some predictions of the model to offer a sense of its implications for more recent behavior. I calibrate the model with data similar to those used in my 1995 calculations. However, ICVS data, which seemed to provide the parameters that allowed the best fit, are not available for the United States after 1999. I use 2004–05 CVS data.

The results, shown in Table 5, are somewhat disappointing, mostly suggesting implausibly large cash demands, even with a high elasticity of crime to money balances. The highest-elasticity results are $865.00 with low noncash costs of crime and $283.91

[16] The Fed figure is seasonally unadjusted and does not include cash held by financial institutions or coins.

with high costs. The equivalent figures for the lowest elasticity considered are $1,287.90 and $750.05. One might suspect that these demands are large because of the dramatic fall in crime that occurred in the late 1990s, which probably reduces the ability of the endogenous crime probabilities to explain low balances. The largest difference between the 1995 and 2004–05 money demands is across all estimates, including the benchmark Baumol-Tobin model with no crime. The explanation partly lies in much larger average nominal nondurable consumption expenditures in 2005 than in 1995—$18,535 versus $12,378—a 38 percent increase in the nominal wage, a more than doubling of the interest rate, and a larger real ATM fee. To determine the effects of reduced crime rates, one can use the 1995 logit parameters for the conditional probability of crime in the 2004–05 computation. As an example, if the Cohen et al. (2004) noncash costs of crime and an elasticity of .0111 are used in the 2004–05 computation (with the 1995 logit parameters replacing the more recent ones), money demand drops from $750.05 to $516.48. This represents a 31 percent decrease or 53.4 percent of the total difference in predicted money demand between the two years. If the model describes behavior well, and cash balances have indeed risen, lower crime rates are the main reason.

5. CONCLUSION

The models presented in this paper offer what I hope is an intuitively appealing answer to the anomaly that Mankiw pointed out in his textbook. The purpose of the paper is not to claim that a simple model such as the second one in this paper can very closely track actual money demand, only to show that it is not hard to generate large enough effects of endogenous crime to offset apparent incentives for counterfactual behavior. Aside from providing an explanation to what appears to be a blatant contradiction of theory, the endogenous crime theory of cash demand may help answer some broader questions. First, the portion of the aggregate stock of cash, as measured by the Federal Reserve, that is not held by U.S. households must be held by someone. Knowing the amount of cash held by U.S. households can help answer questions regarding other types of cash demand, such as cash held abroad and in the black market. Knowledge of the approximate cash holdings of these "dollar economies" allows estimates to be made of their size. A satisfying theoretical explanation may add weight to the evidence provided by the existing household survey data, which contradict estimates obtained in other ways (Flow-of-Funds data, etc.). Since household survey data do not exist for recent years, the estimates for 2004–05 presented in this paper may provide a clue to underground and foreign demand in the absence of direct empirical evidence on household demand.

The calculations here also provide evidence for certain welfare issues. If the best estimate of cash demand for 1995 ($75.98) is considered, U.S. residents spent over 2.35 billion extra hours going to the bank in 1995 because of fear of crime. Using the average wage for production workers, the value of this time was over $27.3 billion, or $37.2 billion in 2007 dollars—a cost of crime that has probably not been sufficiently recognized. Of course, these numbers are inevitably dependent on certain approximations and assumptions that merely seem reasonable, so they should not be taken too seriously as estimates. But they do give a sense of the large costs that might be involved.

APPENDIX 1

This appendix shows how the Bellman equation

$$V(A_t, R_t) = \sup_{C_t,\, M_t} \{u(M_t / P_{t-1}, C_t) - P(M_t / P_{t-1}) w(M_t / P_{t-1}) - g(R_t) + \beta E(V(A_{t+1}, R_{t+1}) \mid M_t / P_{t-1})\}$$

can be reformulated so that one can show:

(1) the supreme value function V*, which gives the sup of all expected utilities attainable by following feasible plans, equals the unique function that satisfies the Bellman equation, and any plan generated by the Bellman function attains the supremum given by V*; and

(2) all plans that attain the supremum are generated by the Bellman function.

These claims correspond roughly with theorems 9.2 and 9.3 of Stokey and Lucas (1989), except that here we specialize to finite state space and a bounded value function. More importantly, our claims involve a Bellman equation with expectations that are conditional on an endogenous choice variable. The purpose of this appendix is to transform the problem so that it uses unconditional expectations, rather than conditional ones, making it clear that the reasoning of Stokey and Lucas's theorems apply.

The new Bellman equation requires some new notation. Let Y_t be a random variable that is uniformly distributed on the unit interval [0,1]. Let $h(Y_t, M_t/P_{t-1})$ be a function defined as follows

$$h(Y_t, M_t / P_{t-1}) = 1$$

if

$$Y_t \leq P(M_t / P_{t-1})$$

and

$$h(Y_t, M_t / P_{t-1}) = 0$$

otherwise.

Using this notation, the Bellman equation is

$$V(A_t, R_t) = \sup_{C_t,\, M_t} \{u(M_t / P_{t-1}, C_t) - P(M_t / P_{t-1}) w(M_t / P_{t-1}) - g(R_t) + \beta E(V(A_{t+1}, R_{t+1})\}$$

where

$$E(V(A_{t+1}, R_{t+1})) = E(V((1+r)(A_t - C_t + y - M_t / P_{t-1}) + (1 - h(Y_t,\, M_t / P_{t-1}))M_t / P_t,\ \alpha R_t +$$
$$h(Y_t, M_t / P_{t-1})))$$
$$= \int_0^1 V((1+r)(A_t - C_t + y - M_t / P_{t-1}) + (1 - h(Y_t,\, M_t / P_{t-1}))M_t / P_{t-1},\ \alpha R_t + h(Y_t,\, M_t / P_{t-1}))\, dY_t$$

Using this form of the Bellman equation, one can prove the first claim at the beginning of this section using the same steps as in theorem 9.2 of Stokey and Lucas (1989, pp. 246–248). A proof of the second claim follows the same reasoning as theorem 9.3 (pp. 251–253).

APPENDIX 2

Consumption is expenditures on nondurable goods and certain services (transportation, recreation, and "other") for the second quarter of 1995 and the first quarter of 2005 from the Bureau of Economic Analysis National Income and Product Accounts, divided by the estimated population 16 years and older from the Bureau of the Census for July 1, 1995 and July 1, 2005. The wage is the average hourly earnings of production workers in the private sector from the establishment survey of the Bureau of Labor Statistics from May of 1995 and January of 2005. The price index is the Consumer Price Index for All Urban Consumers, with annual figures for 1993 and 2000 used for the estimates of Cohen (2001) and Cohen et al. (2004), respectively, and indices for May 1995 and January 2005 used for the 1995 and 2005 estimates of money demand. The estimated probabilities of theft and robbery from the CVS are explained in the text and are from Table 1, Bureau of Justice Statistics (1997) and Table 2, Bureau of Justice Statistics (2006a). Estimated probabilities of crime from the ICVS are from Tables 2 and 6 of Van Kesteren, Mayhew, and Nieuwbeerta (2000). See footnotes to Tables 3, 4, and 5 for details on the crime statistics used. Average fees for a withdrawal, f, for 2005 are taken from Bankrate.com (McBride 2005) and equal a foreign ATM fee of \$1.35, plus an ATM surcharge averaging \$1.40 at 91 percent of ATMs, for a total of \$2.62. ($f = 1.35 + .91*1.40 = 2.62$). No data were available on ATM fees for 1995, but fees have been rising (McBride 2005), so a figure of \$1 was assumed. The interest rate is the one-month CD rate reported by the Federal Reserve.

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TABLES

Table 1. Incidence of Crimes in the United States, Most Recent Published Data

	U.S. Crime Victimization Survey (D.O.J.)(2004–05)[17]	International Crime Victims Survey (1999)[18]
Pick-pocketing and Purse-Snatching	.9	8
Attempted Robbery	.8	
Robbery	1.5	12

Table 2. Incidence of Crimes in the United States, 1995

	U.S. Crime Victimization Survey (D.O.J.)[19]	International Crime Victims Survey[20]
Pick-pocketing and Purse-Snatching	1.9	9
Attempted Robbery	1.9	
Robbery	3.5	16

[17] Incidence rates in this column are number of incidents in the year divided by the population aged 12 and over times 1000. Figures from U.S. Bureau of Justice Statistics (2006a, Table 2). Data from two different years were combined because of small sample size.

[18] Incidence rates in this column are number of incidents in the year divided by the population aged 16 and over times 1000. Robbery statistics are from Table 2 (Van Kesteren, Mayhew, and Nieuwbeerta 2000). Pickpocketing and purse-snatching are listed as simply "pick-pocketing" in Table 6 (Van Kesteren, Mayhew, and Nieuwbeerta 2000).

[19] Incidence rates in this column are number of incidents in the year divided by the population aged 12 and over times 1000. Taken from U.S. Bureau of Justice Statistics (1997, Table 1).

[20] Incidence rates in this column are number of incidents in the year divided by the population aged 16 and over times 1000. Robbery statistics are from Table 2 (Van Kesteren, Mayhew, and Nieuwbeerta 2000). Pickpocketing and purse-snatching are listed as simply "pick-pocketing" in Table 6 (Van Kesteren, Mayhew, and Nieuwbeerta 2000).

Table 3. 1995 Cash Demand in Baumol-Tobin Model with Endogenous Probabilities of Crimes and Crime Incidence Data from the U.S Department of Justice

	Elasticity of Crime to Cash Balances		
Costs of Robbery Other than Loss of Cash	**.0111**	**.0250**	**.1000**
0	525.47	522.49	503.83
Cohen (2001)	509.58	487.86	393.57
Cohen et al. (2004)	312.90	231.79	125.78
No Crime	551.05	551.05	551.05

Table 4. 1995 Cash Demand in Baumol-Tobin Model with Endogenous Probabilities Of Crimes and Crime Incidence Data from the International Crime Victims Survey

	Elasticity of Crime to Cash Balances		
Costs of Robbery Other than Loss of Cash	**.0111**	**.0250**	**.1000**
0	456.80	449.48	412.74
Cohen (2001)	427.95	392.72	284.30
Cohen et al. (2004)	203.81	143.94	75.98
No Crime	551.05	551.05	551.05

Table 5. Cash Demand in Baumol-Tobin Model with Endogenous Probabilities Of Crimes and Crime Incidence Data from the U.S. Crime Victimization Survey (2004–05)

	Elasticity of Crime to Cash Balances		
Costs of Robbery Other than Loss of Cash	**.0111**	**.0250**	**.1000**
0	1337.02	1314.58	1163.36
Cohen (2001)	1287.90	1206.18	865.00
Cohen et al. (2004)	750.05	542.26	283.91
No Crime	1417.95	1417.95	1417.95