# An ARMs Prepayment Model: A Parsimonious Approach

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Agency-issued mortgage-backed securities (MBS) have experienced rapid growth over the past several years. In 1997, combined agency-issued MBS were valued at $368 billion, while more recently, agencies collectively issued $1.4 trillion MBS, according to Fannie Mae's "Economic & Mortgage Market Developments" [2003, p. 14]. The huge size of the mortgage-backed securities market means that uncertainty in the mortgage term poses significant risks to MBS holders, generally institutional investors such as pension funds, financial institutions, or national banks. Prepayments are considered by many to be the most important of these risks (see "A Staff Report" [2003]).

MBS market participants allocate vast resources to model prepayment risk for fixed-rate mortgages (FRMs), adjustable-rate mortgages (ARMs), and various other mortgage types. Modeling mortgage terminations with a degree of certainty tends to be a complex endeavor, especially in the case of ARM-backed securities.

A parsimonious approach put forth in this article suggests a cost-effective and reasonable way to model ARM prepayments without material projection loss as an alternative to more sophisticated models. The approach was initially patterned on Sanyal [1994], who uses historical agency data, and on Parks' [1967] pooled regression procedure. The research differs in several ways, however.

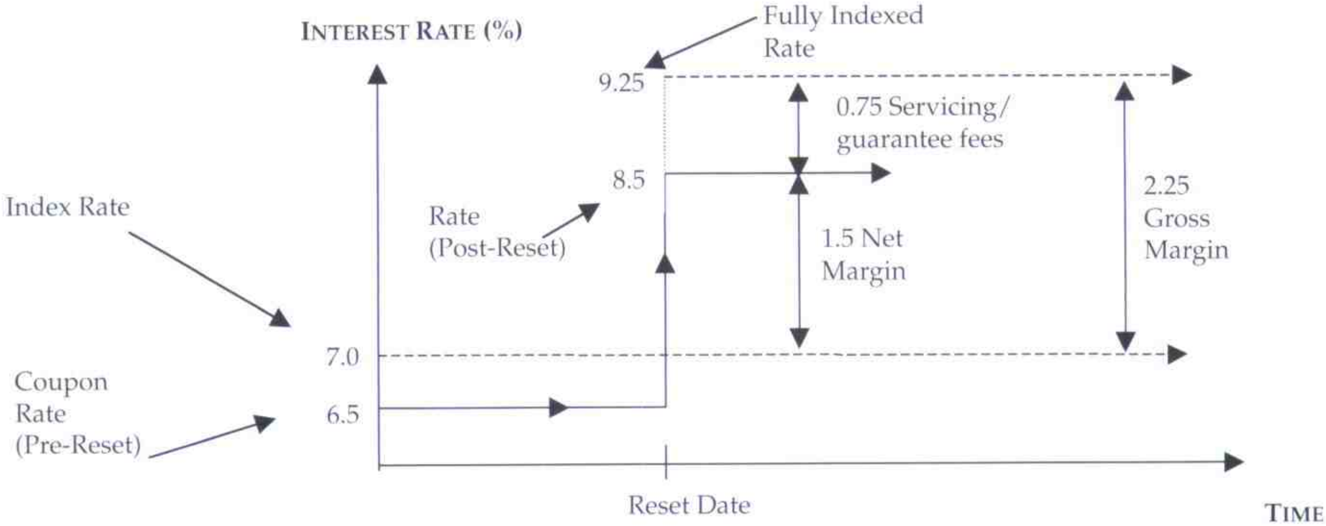
First, I use only Fannie Mae single-family one-year mortgage-backed securities data, while Sanyal uses Fannie Mae, Freddie Mac, and Ginnie Mae data. Second, I use two simple and distinct specifications to measure an economic incentive to refinance.[1] The spread between the current weighted-average coupon (CWAC) less the prevailing one-year constant-maturity treasury (CMT) Treasury constitutes an ARM-to-ARM refinance.[2] Likewise, the spread between the CWAC and the prevailing seven-year Treasury constitutes an ARM-to-FRM refinance. These specifications appear to reasonably capture economic incentives to refinance from an ARM to either another ARM or to an FRM.[3]

## I. STANDARD ONE-YEAR ARM

Adjustable-rate mortgage products differ from other mortgage products in many respects. In an ARM, the contractual rate adjusts or resets to the rate of a specific index. This contractual rate is usually a teaser rate, typically lower than the prevailing market rate of the security to which the mortgage is indexed. For my purposes, the indexed rate refers to the one-year constant-maturity Treasury (CMT), and the ARM adjusts once yearly, usually on the origination date anniversary. Other major ARM indexes include the one-year London Interbank Offered Rate (LIBOR), the 11th District Cost-of-Funds Index (COFI), and the Federal Housing Finance Board (FHFB) national average contract interest rate.[4]

## EXHIBIT 1

**Hypothetical ARM (numbers in %)**




*Source: Adapted from Mansukhani [1997].*

Contractual ARM rates consist of an index rate and a gross margin. The former refers to the prevailing market rate of the security to which the loan is indexed, while the latter equals a spread normally between 200 and 300 basis points (bp), which reflects market conditions, ARM features, and the increased cost of servicing an ARM compared to a fixed-rate mortgage (see Bhattacharya, Fabozzi, and Chang [1997]). The gross margin constitutes two additional components: a net, or security, margin, and a servicing spread (i.e., security guaranty and mortgage servicing fees).[5]

The index rate and the gross margin together yield a fully indexed rate, which may not necessarily equal the effective mortgage rate because of contractual features such as periodic and lifetime caps. Exhibit 1 illustrates how ARM components interrelate.

The coupon rate for this hypothetical ARM is 6.5%, with a net margin of 1.5% (or 150 bp) and an index rate of 7.0%. At the reset date, the coupon rate adjusts to a hypothetical 7.0% index rate. Thus, the fully indexed rate becomes 9.25%. In this scenario, the 9.25% the borrower pays for the adjustable-rate mortgage equals the coupon's reset rate of 7.0% plus the gross margin of 2.25% [or 225 bp = net margin (150 bp) plus servicing and guarantee fees (75 bp)].

Exhibit 1 becomes more complicated when periodic and lifetime caps and floors come into play. A periodic cap is a maximum limit placed on either the contractual interest rate or the mortgage payment during a given period over the life of the ARM. An interest rate periodic cap restricts the percentage change of an interest rate hike on any one reset date. This type of cap protects the homeowner against extreme payment increases, or payment shock. An interest rate periodic floor restricts the percentage change of an interest rate drop on any one reset date. This cap benefits investors as a form of protection against the effects of extreme declines in cash flow.

Lifetime interest rate caps function like periodic caps. The key difference is that a lifetime interest rate cap constrains the maximum adjustment of interest rates over the life of an ARM instead of over a given period.

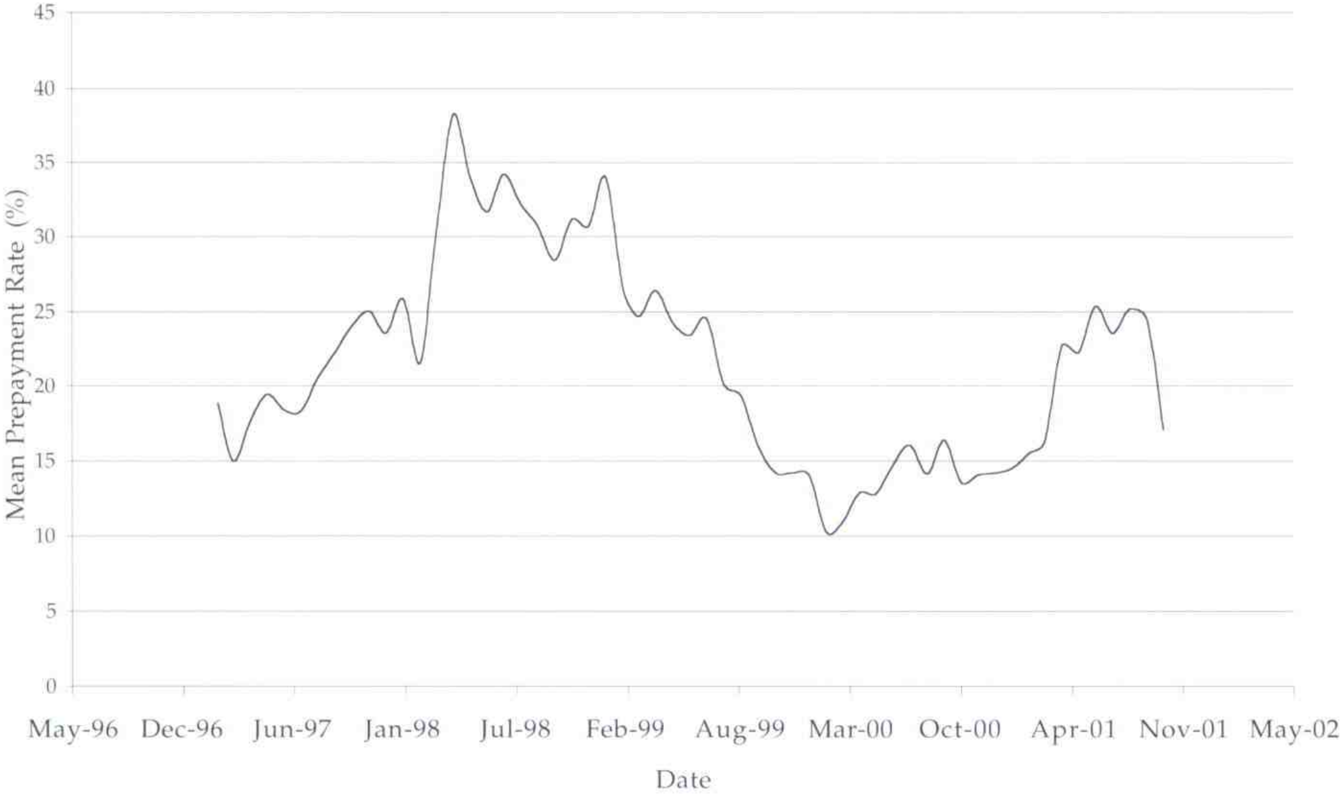
## II. DATA AND MODEL SPECIFICATION

Historical prepayment rate data for my study come from Fannie Mae-issued single-family mortgage-backed securities, indexed to the one-year CMT. Data were accessed via Bloomberg. Issue dates range from 1990 through 1995, and the interest rate environment study period is February 1997–October 2001.

The sample consists of 1,257 unique mortgage-backed security pools and 57 monthly time series points. All mortgage pools are placed in a bucket, from which 57 pools are independently, randomly drawn, run through the time series cross-section (TSCS) procedure to produce results, and then are returned to the bucket. These 57

# EXHIBIT 2

**Mean Prepayment Rate of Fannie Mae Single-Family One-Year MBS 1997–2001**




pools constitute the first sample. The process is repeated multiple times to examine estimate sensitivity across multiple samples.

The Parks time series cross-section procedure is a statistical technique that deals with panel data consisting of time series observations on each cross-sectional unit. This technique permits more information as a result of the pooling process, which increases sample size and degrees of freedom; (see Sanyal [1994, p. 97]. The technique is supported by SAS [1993].

In our case, the pooling of cross-sections and time series points increases the sample size to 71,649 (i.e., 1,257 unique MBS pools × 57 time series points). The Parks version of the TSCS procedure assumes a heteroscedastic, contemporaneously correlated, and first-order autoregressive error structure.

The model is specified as:

$$y_j = b_0 + \sum_{i=1}^{4} b_i x_{ij} + u_j$$

where:

$y$ = historical prepayment speed for Fannie Mae one-year, single family MBS (%);
$x_1$ = pool age (months);
$x_2$ = ARM-to-ARM refinance incentive (CWAC − prevailing 1-year CMT);
$x_3$ = ARM-to-FRM refinance incentive (CWAC − prevailing 7-year CMT); and
$x_4$ = season dummy (1 = April–September and 0 = otherwise).

***Pool Age:*** Prepayment speeds of pooled mortgages are sensitive to the age mix of the underlying mortgages, which can cause the relationship to be non-linear (see Sanyal [1994, p. 97]). Some researchers capture this non-linearity by introducing a quadratic pool age term into the model. Although it is methodologically appropriate, this step may be omitted.

Exhibit 2 shows, for the entire sample, the non-linearity between the mean prepayment speed for single-family one-year Fannie Mae-issued MBS as the pools age over time, from early 1997 through late 2001. The portion of the pool age ranging from 62 to 90 months is relatively linear and downward-sloping. Because of this, and because a significant portion of the sample includes seasoned mortgages, this linear "weight" masks the obvious non-linear association between CPR and pool age assumed in the general prepayment literature. Here, a linear specification can arguably be employed to fit the data, with some caution.

***Refinance Incentive:*** An economic incentive to refinance is consistently one of two core prepayment predictors. In a general declining interest rate environment, some ARM borrowers prepay their loans to refinance at the lower rate into another mortgage instrument such as another ARM, or fixed-rate mortgage, or hybrid. ARM-to-ARM and ARM-to-FRM refinancing, or switching, appear to be the most prevalent choices of borrowers seeking to refinance by locking in long-term lower rates.

My prepayment model consists of two distinct incentive to refinance specifications. The ARM-to-ARM incentive to refinance equals the CWAC less the prevailing one-year CMT; the ARM-to-FRM incentive to refinance equals the CWAC less the prevailing seven-year CMT.

There is some flexibility in choosing the FRM proxy. During early model development, the ten-year CMT was used, but it seemed less robust under different interest rate scenarios. Thus, the seven-year CMT was chosen, which is used as a proxy for the rate available on alternative fixed-rate mortgages.

The slope of the yield curve most appropriate for the current model appears to be the spread between the seven- and one-year U.S. Treasuries. As expected, the relationship between this spread and prepayment speed is negative, implying that when the spread tightens, or this portion of the yield curve becomes flatter, interest rates on longer-term fixed-rate mortgages become less expensive. A homeowner holding a high-coupon ARM may be more inclined to switch into a fixed-rate mortgage.

Some of the prepayment literature includes LIBOR-based indexes rather than CMT-based ones, although the latter are sufficient for my research purposes.

***Burnout:*** Burnout is not specified in this parsimonious model because it is theorized to have an immaterial effect in prepayment rates for adjustable-rate one-year mortgages. The burnout variable can be viewed in several different ways.[6]

One way is to see burnout as varied borrower responsiveness to refinance incentives. That is, some borrowers, say, group one, may be more informed about refinancing availability, and more financially sophisticated, and attempt to refinance at an optimal time. So, within a pool of borrowers, group one would burn out faster than others. Group two may be less informed and financially astute; they would burn out at a slower average pace than group one borrowers. Viewed this way, burnout is some broad reflection of borrower differences with respect to some refinance incentive.

These particular differences, however, may not necessarily materially impact prepayment rates for one-year ARM borrowers. The reason is that an automatic refinancing component, at zero transaction cost, is implicitly imbedded in a one-year adjustable-rate mortgage through the reset mechanism. The burnout phenomenon is thus assumed to play an immaterial role in prepayments of one-year ARMs.

***Season Dummy:*** While the incentive to refinance is one of two primary prepayment predictors, the incentive to move or relocate is the other. Borrowers move for many reasons. Chief among them are home appreciation cash-out, job relocation, and residential upgrade. To model each of the multiple components driving an incentive to move is exceedingly complex, but a more cost-effective approach to capture a portion of borrower moving would be useful.

A simple measure to partially capture borrower moving is "dummy" housing turnover. Regardless of the motivation to move, some research indicates that housing turnover generally follows a seasonal pattern, with summer highs and winter lows (see McConnell and Singh [1991] and Hayre, Chaudhary, and Young [2000]). So, assigning one to months April through September, and zero otherwise, may capture some degree of borrower moving without needing to rely upon the many different assumptions needed to model borrower motivations to move.

## III. INITIAL RESULTS

Exhibit 3 shows parameter estimates from the TSCS Parks procedure. Given the 1997–2001 interest rate period, the ARM-to-ARM incentive to refinance, 2.80, seems to be the strongest predictor of prepayment speeds for Fannie Mae single-family one-year adjustable-rate mortgage-backed securities, which indicates that a 100 basis point increase in the spread between the CWAC on the underlying mortgage and the prevailing one-year CMT increases the prepayment speed for these particular MBS by 2.8%, controlling for other effects. The ARM-to-FRM incentive to refinance, 2.27, is the second-strongest

**EXHIBIT 3**

**Parameter Estimates for Prepayment Model**

| Independent Variable | Parks Estimate | Standard Error | $t$-statistic |
|---|---|---|---|
| Intercept | 23.92 | 0.2798 | 85.48*** |
| Pool Age | -0.21 | 0.0017 | -124.83*** |
| ARM-to-ARM Refinance | 2.80 | 0.2493 | 11.25*** |
| ARM-to-FRM Refinance | 2.27 | 0.2687 | 8.43*** |
| Season Dummy | 1.72 | 0.1512 | 11.38*** |
| RMSE | | | 0.99 |

*** $p < 0.001$.

predictor of prepayment speeds.

These findings appear consistent with other empirical findings in that the incentive to refinance is one of the most consistently robust predictors of prepayment speeds.

Exhibit 4 compares actual and estimated mean prepayment speeds for Fannie Mae one-year mortgage-backed securities. For the 1997–2001 time period, the comparison of actual versus projected average prepayment speeds appears reasonable. The fit between mean actual and forecasted estimates for 3Q97-4Q97 and 1Q99–4Q00 seems particularly good. Conversely, in several instances during the 1997–2001 period, model estimates appear spotty, especially in the mid-1997s and the majority of 1998.

At this stage of the research, it is unclear exactly why the model performs less well during certain time periods, but there is some evidence in the literature suggesting that prepayment rates are relatively high—sometimes as much as 50% or more—during strong market rallies, say, in 1998. In these conditions, an accurate modeling of refinancing behavior is needed, and a parsimonious specification becomes costly.

Exhibit 4 indicates that forecasted estimated prepayment rates for one-year single-family mortgage-backed securities clearly underpredicted actual prepayment speeds for the majority of 1998. At first glance, we might conclude that a parsimonious approach either under- or overprojects prepayment rates for reasons of omitted variable bias.

## IV. SUMMARY

I have shown how to project prepayment risk of Fannie Mae-issued single-family one-year mortgage-backed securities using historical pool-level data and a publicly available pooled regression procedure. The limitations of this and other parsimonious models should be clear, of course. The first limitation is generalizability. While out-of-sample testing produced results quite comparable to the in-sample results, applying this approach to other agency-issued adjustable-rate mortgage-backed securities and under different interest rate scenarios would provide a broader picture of model performance.

Other limitations of a simple approach include misspecification and estimator selection. Non-linear elements in some of the relationships may make a switcher or spline model a more suitable estimator than the TSCS Parks approach used here. Lastly, other straightforward refinancing incentive specifications are also available.

This research finds some corroborative evidence that 1) a parsimonious prepayment speed model, using publicly available information, can be developed to monitor prepayment speeds of agency-issued ARM-backed securities, and that 2) the ARM-to-ARM and ARM-to-FRM incentives to refinance appear to be the main drivers of prepayments for these securities.

The issue as to whether a "decent ARMs prepayment model can be built fairly simply" is an empirical question, better addressed by rigorous testing under different interest rate scenarios and varying variable specifications. Such a prepayment model does provide some insight into the usefulness of a simple approach to prepayment modeling of adjustable-rate mortgages, particularly in cost-effectiveness.

## EXHIBIT 4
**Actual-Estimated Mean Prepayment Speed Comparison for One-Year ARMs**

| | Prepayment Rate | |
|---|---|---|
| | Actual | Estimated |
| Feb-97 | 17.46 | 24.97 |
| Mar-97 | 16.40 | 23.54 |
| Apr-97 | 19.62 | 27.97 |
| May-97 | 19.55 | 25.89 |
| Jun-97 | 22.29 | 24.45 |
| Jul-97 | 19.60 | 25.48 |
| Aug-97 | 19.10 | 26.57 |
| Sep-97 | 22.98 | 23.67 |
| Oct-97 | 22.56 | 23.44 |
| Nov-97 | 20.69 | 23.33 |
| Dec-97 | 25.23 | 23.85 |
| Jan-98 | 20.67 | 24.30 |
| Feb-98 | 20.83 | 24.24 |
| Mar-98 | 32.59 | 25.50 |
| Apr-98 | 35.99 | 28.59 |
| May-98 | 30.79 | 27.70 |
| Jun-98 | 32.23 | 27.36 |
| Jul-98 | 31.86 | 26.37 |
| Aug-98 | 33.50 | 26.77 |
| Sep-98 | 27.92 | 23.14 |
| Oct-98 | 26.39 | 23.75 |
| Nov-98 | 31.16 | 26.57 |
| Dec-98 | 29.83 | 28.43 |
| Jan-99 | 37.26 | 25.26 |
| Feb-99 | 26.76 | 25.29 |
| Mar-99 | 24.21 | 24.14 |
| Apr-99 | 25.51 | 25.52 |
| May-99 | 24.45 | 23.91 |
| Jun-99 | 21.22 | 23.86 |
| Jul-99 | 28.16 | 21.44 |
| Aug-99 | 24.45 | 18.84 |
| Sep-99 | 20.10 | 15.26 |
| Oct-99 | 14.87 | 13.92 |
| Nov-99 | 13.87 | 13.74 |
| Dec-99 | 12.72 | 13.25 |
| Jan-00 | 15.36 | 14.05 |
| Feb-00 | 10.45 | 12.71 |
| Mar-00 | 13.23 | 11.03 |
| Apr-00 | 13.72 | 14.81 |
| May-00 | 13.89 | 15.67 |
| Jun-00 | 19.48 | 17.38 |
| Jul-00 | 13.07 | 15.97 |
| Aug-00 | 16.31 | 18.07 |
| Sep-00 | 17.18 | 15.66 |
| Oct-00 | 19.22 | 16.43 |
| Nov-00 | 16.02 | 17.06 |
| Dec-00 | 12.44 | 18.01 |
| Jan-01 | 15.59 | 18.24 |
| Feb-01 | 20.53 | 21.12 |
| Mar-01 | 10.35 | 23.27 |
| Apr-01 | 16.34 | 26.29 |
| May-01 | 21.60 | 27.69 |
| Jun-01 | 30.32 | 26.78 |
| Jul-01 | 29.32 | 24.97 |
| Aug-01 | 26.73 | 24.55 |
| Sep-01 | 32.55 | 19.73 |
| Oct-01 | 20.19 | 19.71 |
| $R^2 = 0.99$ | | |

## ENDNOTES

The author thanks Jeffrey Brown, Michael Carhill, Jason Dietrich, Dennis Glennon, and P.C. Venkatesh; discussion participants; and an anonymous reviewer for their feedback on earlier versions. Views expressed are the author's, and do not necessarily reflect the views of either the Office of the Comptroller of the Currency or the U.S. Department of the Treasury.

[1]See Chatterjee [1999], who presents two methods to measure the refinance phenomenon. ARM-to-ARM and ARM-to-fixed-rate refinancings occur when borrowers refinance from an ARM into another ARM or from an ARM into a fixed-rate mortgage.

[2]The one-year CMT is the average yield of all Treasury securities with one year remaining until maturity. The index is calculated weekly or monthly using market reports by five leading government securities dealers. The weekly index is published each Monday in the Federal Reserve Statistical Release H. 15 (519) and can be accessed on various wire services (see www.fanniemae.com, 2003).

[3]See Hayre and Young [2001, Chapter 4]. One other way to capture the refinance incentive is the ratio of weighted-average coupon-to-prevailing market rate. Another way is to measure a "percentage saving" from refinancing as follows:

$$\% \text{ Savings} = 1 - (M/C)[(1 - x^{w})/(1 - y^{w})][1 + v + (F/B)]$$

where M = prevailing mortgage rate (on new loans);
C = rate on current loan;
X = [1/(1 + C)];
W = remaining term of loan (in months);
Y = [1 / (1 + M)]; and
B = current loan balance.

[4]LIBOR is the rate at which major international banks offer to place deposits with one another for maturities from overnight to five years. It has become a popular index worldwide. Index options range from a one-month to one-year LIBOR. Fannie Mae offers several index options as well, but the most common securitized Fannie Mae ARM MBS are six-month and one-year LIBOR.

The 11th District COFI is determined by the monthly weighted-average cost of savings, borrowings, and advances for member institutions of the 11th District Federal Home Loan Bank (FHLB), which includes Arizona, California, and Nevada. The FHLB of San Francisco reports this index on the last business day of the month. COFI has traditionally reacted more slowly than Treasuries to short-term market rate movements, in part because of the varying maturities of the liabilities that make up the index. See Stanton and Wallace [1994].

[5]See "Understanding Fannie Mae Mortgage-Backed Securities" [2003].

[6]Hayre [1994] provides persuasive approaches to modeling burnout and incentive.

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