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1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA16-2854		

4. TITLE AND SUBTITLE
Traffic Volume and Aggregate Economic Activity: Implications for Taking the Pulse of the U.S. Economy

5. REPORT DATE
September 2016

6. PERFORMING ORGANIZATION CODE

7. AUTHOR
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8. PERFORMING ORGANIZATION REPORT NO.
UCTC-FR-2016-04

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Institute of Transportation Studies, Haas School of Business
University of California Berkeley
109 McLaughlin Hall, Berkley, CA 94720-1720

10. WORK UNIT NUMBER

11. CONTRACT OR GRANT NUMBER
65A0528

12. SPONSORING AGENCY AND ADDRESS
Department of Transportation
Division of DRISI-HQ
MS #38
P. O. Box 942874
Sacramento, CA 94274-0001

13. TYPE OF REPORT AND PERIOD COVERED
Final Report
2/1/2015 - 9/30/2016

14. SPONSORING AGENCY CODE
Caltrans DRISI

15. SUPPLEMENTARY NOTES
N/A

16. ABSTRACT
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17. KEY WORDS	18. DISTRIBUTION STATEMENT
Vehicle Miles Traveled (VMT), Gross Domestic Output (GDP), economic activity, mathematical models	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	24	N/A

DISCLAIMER

University of California Transportation Center
UCTC-FR-2016-04

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December 2016

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ABSTRACT

What is the incremental relevance of real-time traffic volume data for taking the pulse of the U.S. economy? Although prior research has identified a positive (bi-directional) link between traffic volume and economic activity, there is a dearth of evidence on the relevance of traffic volume information for taking the pulse of the U.S. economy. This is because, by and large, macroeconomics research has evolved independently from transportation research. Our study breaks new ground for interdisciplinary research by focusing on the relevance of aggregate traffic volume data for gauging fluctuations in economic growth. Using data from the Traffic Volume Trends (TVT) reports of the Federal Highway Administration of the U.S. Department of Transportation, we construct a real-time index of Vehicle Miles Traveled (VMT) growth and deliver four main messages. First, we show that seasonally-adjusted VMT growth is closely related to employment growth and real Gross Domestic Output (GDP) growth. Second, this relation strengthens as we move from the initial estimates of economic activity to more recent vintages, which are closer to the true state of the U.S. economy. Third, our index of VMT growth has incremental predictive content for the revisions in the initial estimates of employment growth and real GDP growth. Fourth, our analysis of the granular origins of aggregate VMT fluctuations shows that the index of aggregate VMT growth can be constructed in a cost-effective way by focusing on a subset of key states. Indeed, we find evidence of diminishing marginal benefits from adding more states in the aggregation process beyond the top-10 states in terms of contribution to aggregate VMT. Our analysis of the granular origins of aggregate VMT fluctuations also highlights the importance of state of California for gauging fluctuations at the federal level. Indeed, we find that on a stand-alone basis California VMT growth explains as much as 64% of the time-series variability of aggregate VMT growth. This result is striking given that California VMT accounts for 11% of the aggregate VMT level. Overall, our findings have important implications for a wide array of decision makers, including the Federal Reserve when formulating monetary policy and capital markets participants when making investment decisions, and can lead to significant improvements in the measurement of economic activity in real-time. We believe that our report will serve as the starting point for several follow-up studies on the interplay of VMT and economic activity both at the federal and at the state level.

1. INTRODUCTION

1.1 Problem Statement

What is the current state of the U.S. economy? The answer to this question is the "holy grail" for macroeconomists and a wide range of decision makers. Indeed, GDP adjusted for inflation is the key summary statistic of economic activity (e.g., Bureau of Economic Analysis, 2007) and the most important variable in analyses of economic growth (e.g., Aruoba et al., 2013). [1] It is used by the White House and Congress to prepare the Federal Budget, by the Federal Reserve to formulate monetary policy, by Wall Street as an indicator of economic activity, and by the business community as a key input for production, investment, and employment decisions.

Although prior research in transportation and urban planning has identified a positive, bidirectional link between traffic volume and economic activity (see, e.g., McMullen and Eckstein, 2012, and the references therein), there is a dearth of evidence on the relevance of traffic volume information for gauging the state of the U.S. economy in real time. This is because, by and large, macroeconomics research has evolved independently from research in other disciplines. Our study breaks new ground for interdisciplinary research in macroeconomics and transportation by focusing on the relevance of real-time traffic volume data for gauging fluctuations in the U.S. economy.

Traffic volume data can be used to construct long time-series of indices not only at the state-level but also at the federal-level. Our research questions focus on the potential of such aggregate indices to serve as coincident indicators of overall economic activity. A contemporaneous link

[1] While GDP growth is the most important variable in analyses of economic growth, it is not a measure of societal well-being and does not account for environmental degradation, crime, or literacy (e.g., Stiglitz et al., 2010).

between aggregate traffic volume data and overall economic activity would suggest that such data can be relevant for *nowcasting* GDP growth.

1.2 Objectives of the Study

Our investigation of the link between aggregate traffic volume data and macroeconomic activity has the potential to inform professional macro forecasters stuffing the U.S. Government, which routinely uses GDP growth forecasts when developing the Federal Budget, and the Federal Reserve, which considers GDP growth forecasts as central for monetary policy making. If aggregate traffic data embed information relevant for forecasting GDP growth in real time, then it is possible such data can be used to improve consensus forecasts of current quarter GDP growth and, in turn, employment growth. Given that consensus GDP forecasts are central for policy making any evidence of improvability based on our indices becomes *de facto* important.

Overall, we cannot help but feel excited about the potential of our report not only to break new ground for interdisciplinary research but also to inform policy making using aggregate traffic volume data. We are also excited about the potential of our study to address key issues that are relevant to California. First, our real-time indices of traffic volume data when aggregated at the state-level can be used for forecasting current economic activity in California. Second, given that economic activity is inexorably linked to labor market conditions, our study is poised to shed new light on the link between traffic volume growth, employment growth, and unemployment rates in California. Third, our study can address the question whether traffic conditions in California can serve as a "bellwether" indicator for economic activity in other states as well as for taking the pulse of the entire U.S. economy.

1.3 Organization of the Report

Our report is organized as follows. Section 2 describes our data collection efforts. Section 3 reports our analyses. Section 4 concludes.

2. DATA COLLECTION

2.1 Data collection—Traffic Volume Data

The starting point in our investigation of the link between traffic volume data and overall economic activity are the Traffic Volume Trends (TVT) reports—a monthly publication by the Federal Highway Administration (FHWA) Office of Highway Policy Information, U.S. Department of Transportation.

The TVT reports include information about Vehicle Miles Traveled (VMT) on all U.S. public roads on a monthly basis. The reports are based on traffic data from the Highway Performance Monitoring System and on data submitted to the FHWA by State highway agencies throughout the entire U.S. The State highway agencies collect the data through permanent automatic traffic recorders (ATR) on public roadways. Monthly permanent traffic recorder data should be submitted to the FHWA within 20 days after the closing of the month. For example, the January 2016 data should be submitted to FHWA no later than February 20, 2016.

2.2 Time-Series of Aggregate VMT Data

Figure 1 presents the time-series variation of the level of aggregate VMT expressed in millions of miles at quarterly frequencies. Our sample covers the period from 1971 to 2015. A visual inspection reveals a seasonal effect in the aggregate VMT data. Specifically, the evidence shows that aggregate VMT drops in the fourth quarter due to winter weather.

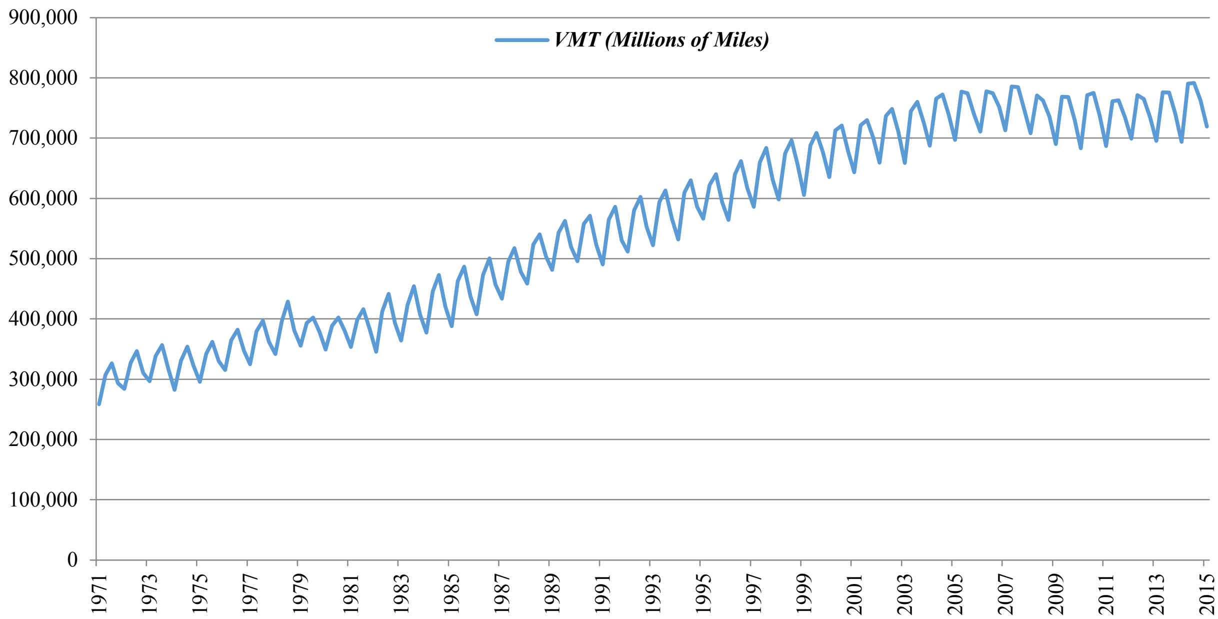

Figure 1: Time-series of aggregate VMT level

2.2 Seasonally-Adjusted VMT Growth

The primary focus of our analysis is to explain variation in the growth rate rather than the level of economic activity. Therefore, our empirical analysis is based on the growth rate of VMT. To mitigate the seasonal effects in aggregate VMT data, we construct our index of aggregate VMT growth using the year-over-year percentage changes in VMT:

$$VMT\ Growth_q = \frac{VMT_q - VMT_{q-4}}{VMT_{q-4}}$$

Figure 2 presents the time-series variation of our index of aggregate VMT growth for our full sample period.

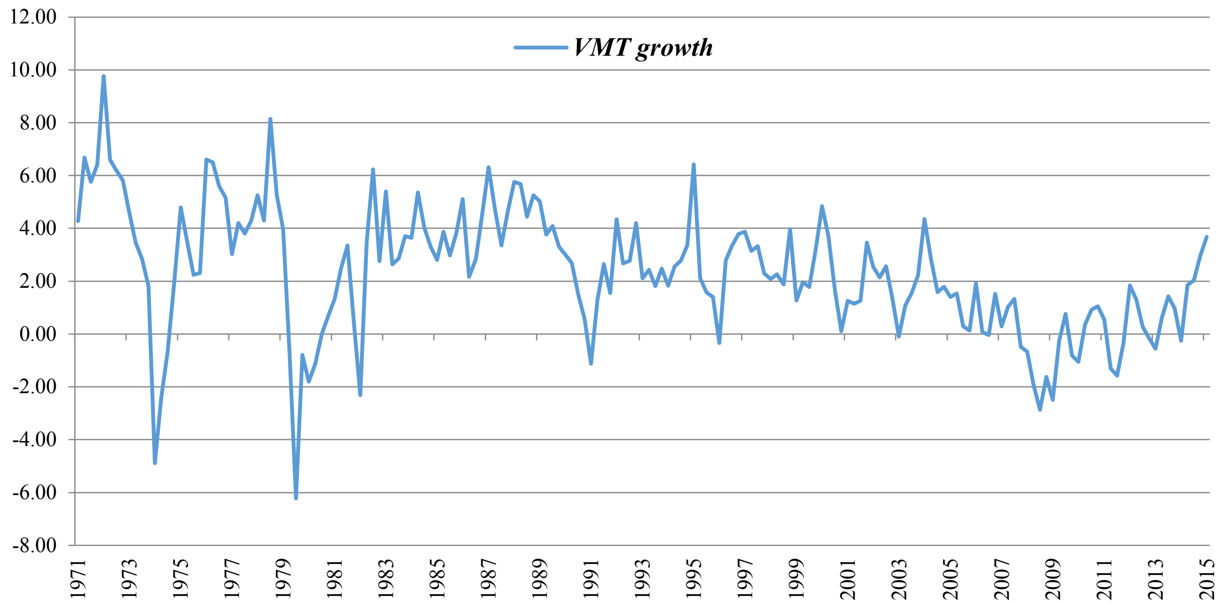

Figure 2: Time-series of seasonally-adjusted aggregate VMT growth

The time-series mean value of our index of seasonally-adjusted VMT growth is close to 2%. Figure 2 shows, however, that this mean value masks considerable variation over our sample period. Our subsequent analyses show that time-series variability in our index of VMT growth is closely related to real economic activity.

2.3 Macroeconomic-Series Data

Our sources for macroeconomic series include the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce for real GDP growth realizations and the Department of Labor Statistics for employment growth realizations. A key aspect of our research design is that we carefully consider the timing of the macro releases and align the traffic volume series and the macroeconomic-series data.

We obtain the historical realization vintages from the Real-Time Dataset for Macroeconomists available from the Philadelphia Fed of the Federal Reserve System. The realization vintages we consider include (i) the initial releases one month after the end of the quarter (also known as advance estimates); (ii) the values available one quarter after initial release; (iii) the values available five quarters after initial release; and (iv) the values available nine quarters after initial release (also known as final estimates).

The initial estimates of macroeconomic growth are based on incomplete data and are subject to significant revisions. The revised estimates are more reliable representations of the state of the economy. Empirically we observe that the revisions can be substantial especially around turning points in the business cycle. Indeed, we see that the official measurements of the U.S. economy tend to be revised downwards when the economy is turning into a recession and upwards when the economy is slipping out of the recession. A priori, however, one would expect that revisions in the official estimates of economic activity should be randomly distributed over time.

3. ANALYSIS

3.1 Merging Traffic and Macroeconomic Data

As explained in Section 2, a key aspect of our research design is that we carefully consider the timing of the macro releases and align the traffic volume series and the macroeconomic-series data. This way we ensure that our seasonally-adjusted index of aggregate VMT growth is available in real-time for taking the pulse of the U.S. economy.

3.2 Methodology

Throughout our report, we estimate our models using ordinary least squares (OLS) regressions and we base statistical inferences on Newey and West (1987) heteroskedasticity and autocorrelation consistent standard errors. Following Greene (2001), we set the lag length for the Newey-West procedure equal to the integer part of $N^{0.25}$, where N is the number of quarters in our sample. Accordingly, we set the lag length equal to three. Our inferences are not sensitive when we vary the lag length from zero, which is equivalent to using White's (1980) heteroskedasticity consistent standard errors, to four.

3.3 Aggregate VMT growth and real economic activity

Our first set of analyses search for a link between our real-time index of aggregate VMT growth and real GDP growth. Table 1 reports results from time-series regressions of the different vintages of the realizations of real GDP growth (first panel) and employment growth (second panel) on our index of VMT growth. The realization vintages we consider include the advance, the second, the third, and the final reports.

	Dependent Variable = Real GDP growth			
Realization	Initial	Second	Third	Final
Intercept	1.28	1.33	1.30	1.06
t-statistic	*3.65*	*3.45*	*3.48*	*2.84*
p-value	*0.00*	*0.00*	*0.00*	*0.01*
VMT growth	**0.51**	**0.55**	**0.55**	**0.63**
t-statistic	*5.24*	*5.26*	*5.49*	*6.25*
p-value	*0.00*	*0.00*	*0.00*	*0.00*
Adj. R^2	**14.4%**	**14.7%**	**14.9%**	**19.9%**

	Dependent Variable = Employment growth			
Realization	Initial	2	3	Final
Intercept	0.51	0.51	0.44	0.42
t-statistic	*2.08*	*2.05*	*1.71*	*1.61*
p-value	*0.04*	*0.04*	*0.09*	*0.11*
VMT growth	**0.41**	**0.42**	**0.45**	**0.47**
t-statistic	*5.63*	*5.63*	*5.95*	*6.22*
p-value	*0.00*	*0.00*	*0.00*	*0.00*
Adj. R^2	**21.3%**	**21.7%**	**24.4%**	**25.1%**

Table 1: Explaining time-series variation in real economic activity using VMT growth

The regression results in Table 1 establish that there is a significantly positive link between real economic activity and VMT growth. In fact, the evidence shows that this link *strengthens* as we get closer to the true state of the U.S. economy.

Starting with real GDP growth, we document that our index of VMT growth explains 14.4% of the time-series variation of the first measurement—also known as advance report—of real GDP growth. The explanatory power of VMT growth rises to 19.9% as we move from the advance report to the final report of GDP growth. In addition, the slope coefficient on VMT growth, which measures the elasticity of real GDP growth to VMT growth, rises from 0.51 to 0.63.

Turning to employment growth, our evidence of a significantly positive link between real economic activity and VMT growth becomes even more striking in terms of explanatory power. Specifically, we document that our index of VMT growth explains 21.3% of the time-series variation of the first measurement of employment growth. The explanatory power of VMT growth rises to 25.1% as we move from the first report to the final report of employment growth. Similarly, the slope coefficient on VMT growth, which measures the elasticity of employment growth to VMT growth, rises from 0.41 to 0.47.

A key implication of our evidence is that the link between aggregate VMT growth and real economic activity strengthens as we get closer to the true state of the U.S. economy. Therefore, our real-time index of aggregate VMT growth is relevant for nowcasting real economic activity. Nowcasting—a term derived from the contraction of *now* and *forecasting*—is defined as the assessment of current-quarter real economic activity.

3.4 Predictability of revisions in the official realizations of real economic activity

The evidence presented so far shows that our seasonally-adjusted index of VMT growth is relevant for nowcasting current quarter real GDP growth and employment growth. Importantly, our evidence shows that the nowcasting ability of VMT growth increases as we move from the advance measurement to the final measurement of real economic activity.

Our second set of analyses focus on predicting revisions to the official measurements of U.S. economic activity. Table 2 reports results from time-series regressions of the revision from the advance to the final report of real GPD growth (first column) and employment growth (second column).

	Dependent Variable = Revision from Advance to Final Estimate	
	Real GDP growth	Employment Growth
Intercept	-0.20	-0.11
t-statistic	*-1.23*	*-1.88*
p-value	*0.22*	*0.06*
VMT growth	**0.17**	**0.06**
t-statistic	*3.15*	*3.67*
p-value	*0.00*	*0.00*
Intial Estimate	-0.15	-0.01
t-statistic	*-3.56*	*-0.22*
p-value	*0.00*	*0.82*
Stock Returns	0.02	0.00
t-statistic	*2.83*	*0.84*
p-value	*0.01*	*0.40*
Adj. R^2	10%	7%

Table 2: Predicting revisions in measurements of real economic activity using VMT growth

In our regression model, we include the initial estimate of economic growth along with stock market returns as additional predictors. The reason why we include the initial estimate of economic growth as a predictor is that to the extent that the initial report is an unbiased estimate of the final report, the initial report should be unrelated to the revision from the initial report to the final report. The reason why we include stock returns as a predictor is that stock market participants can also be envisaged as another group of macro- nowcasters. Indeed, prior research finds that stock returns anticipate real economic activity consistent with rational expectations asset pricing models (e.g., Fama 1981; Fischer and Merton 1984; Barro 1990; Fama 1990). Therefore, a question of particular relevance is whether the nowcasting content of our index of VMT growth is incremental to that of stock market returns. We use the CRSP value-weighted index (including distributions) to proxy for the stock market portfolio, and measure annual buy-and-hold returns.

The regression results in Table 2 provide consistent evidence that revisions in estimates of real GDP growth and employment growth are predictable based on VMT growth. Importantly, our evidence shows that the predictive ability of VMT growth for subsequent macro revisions is incremental to that of the initial reports and stock market returns.

Evidence of predictability in the revisions of the official measurements of real GDP growth and employment growth is of paramount important to a wide array of decision makers, including the Federal Reserve when formulating monetary policy, the White House when setting the Federal Budget, businesses when making investment decisions, and capital market participants when setting asset prices.

Our findings can inform the BEA of the U.S. Department of Commerce and the Bureau of Labor Statistics when measuring the U.S. economy. Indeed, our communication with macroeconomists suggests that our index of VMT growth has the potential to be incorporated in nowcasting statistical factor models geared towards taking the pulse of the U.S. economy in real time.

3.5 Extracting VMT Data in a Cost-Effective Way: The Role of California and other Key States

Our analyses so far provide evidence that our index of aggregate VMT growth is incrementally relevant for nowcasting current quarter real GDP growth and employment growth. In our final set of analyses, we examine whether our index can be constructed in a cost-effective way by focusing on a subset of key states. Our analyses also explicitly consider the contribution of the state of California in aggregate VMT activity as well as its role for understanding aggregate VMT fluctuations at the federal level along with other bellwether states.

Table 3 reports historical information about the percentage contribution of each state (including the District of Columbia) to aggregate VMT. To ease the presentation, states are ranked in descending order starting from the state with the highest contribution to aggregate VMT.

Ranking	State	% VMT contribution
1	California	11.0
2	Texas	8.1
3	Florida	6.6
4	New York	4.5
5	Georgia	3.7
6	Ohio	3.7
7	Illinois	3.5
8	Pennsylvania	3.5
9	North Carolina	3.5
10	Michigan	3.3
11	Virginia	2.7
12	Indiana	2.5
13	New Jersey	2.4
14	Tennessee	2.4
15	Missouri	2.3
16	Alabama	2.1
17	Arizona	2.0
18	Wisconsin	2.0
19	Minnesota	1.9
20	Washington	1.9
21	Maryland	1.9
22	Massachusetts	1.8
23	South Carolina	1.7
24	Oklahoma	1.6
25	Colorado	1.6
26	Kentucky	1.6
27	Louisiana	1.5
28	Mississippi	1.4
29	Oregon	1.2
30	Arkansas	1.1
31	Connecticut	1.1
32	Iowa	1.0
33	Kansas	1.0
34	Utah	0.9
35	New Mexico	0.8
36	Nevada	0.7
37	West Virginia	0.7
38	Nebraska	0.7
39	Idaho	0.5
40	Maine	0.5
41	New Hampshire	0.4
42	Montana	0.4
43	Hawaii	0.3
44	Wyoming	0.3
45	Delaware	0.3
46	South Dakota	0.3
47	North Dakota	0.3
48	Rhode Island	0.3
49	Vermont	0.3
50	Alaska	0.2
51	District of Columbia	0.1

Table 3: Percentage contribution of each state to aggregate VMT

Table 3 clearly highlights the role of California as a key state in terms of gauging aggregate fluctuations in aggregate activity. Specifically, our analysis of historical data show that the state of California accounts for as much as 11% of aggregate VMT, followed by Texas, Florida, and New York, which account for 8.1%, 6.6%, and 4.5%, respectively, of aggregate VMT. The top-10 states in combination account for nearly 52% of aggregate VMT activity.

These observations are important because they open up the possibility of a granular-origins approach to extracting VMT data that focuses on a subset of key states across the U.S., including the state of California. Figure 3 provides the micro-foundation towards a cost-effective way to extracting VMT data at the aggregate level.

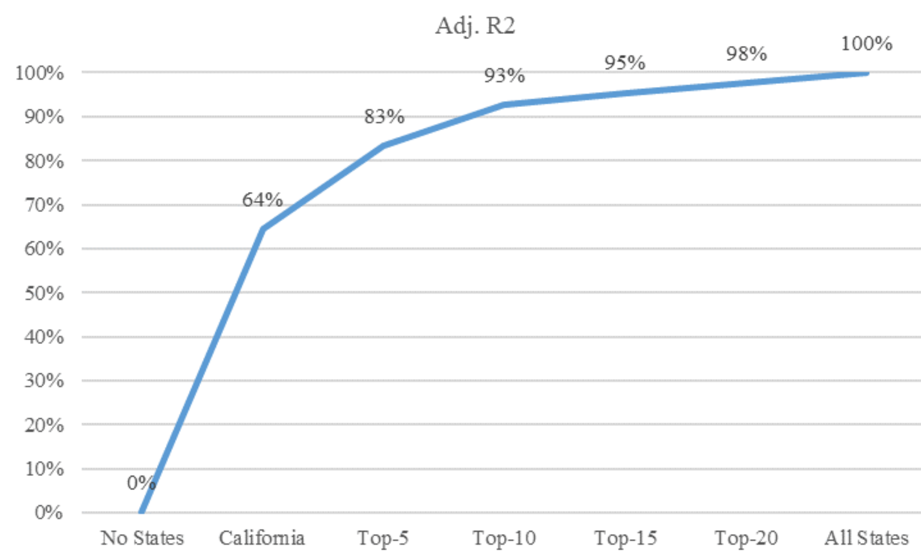

Figure 3: A granular-origins approach to extracting VMT data

In particular, Figure 3 reports the adjusted R^2 from regressions of our index of aggregate VMT growth on the VMT growth of (i) California, which is the top state in terms of contribution to aggregate VMT; (ii) the VMT growth of the top-5 states (i.e., California, Texas, Florida, New

York, and Georgia); (iii) the VMT growth of the top-10 states; (iv) the VMT growth of the top-15 states; (v) the VMT growth of the top-20 states; and (vi) the VMT growth of all states, which is 100% by definition.

Figure 3 shows that on a stand-alone basis California VMT growth explains as much as 64% of the time-series variability of aggregate VMT growth. This result is striking given that California VMT accounts for 11% of the aggregate VMT level. This finding highlights the importance of the state of California for gauging fluctuations at the federal level.

Figure 3 also shows evidence of diminishing marginal benefits from adding more states in the aggregation process. Indeed, the VMT growth of the top-5 states explains as much as 83% of the time-series variability of aggregate VMT growth. The adjusted R^2 increases to 93% using the top-10 states and only modestly from that point onwards. The evidence illustrates that much of the variability in aggregate VMT growth can be explained by the VMT growth of the top-10 states, including California, Texas, Florida, New York, and Georgia, Ohio, Illinois, Pennsylvania, North Carolina, and Michigan. By far the single state with the most significant contribution in terms of explaining time-series variability in the aggregate VMT growth is California.

4. CONCLUSIONS

Our report breaks new ground for interdisciplinary research by focusing on the relevance of aggregate traffic volume data for gauging fluctuations in economic growth. Using data from the TVT reports of the Federal Highway Administration of the U.S. Department of Transportation, we construct a real-time index of VMT growth and deliver four main messages.

First, we show that a real-time index of seasonally-adjusted VMT growth is closely related to employment growth and real Gross Domestic Output (GDP) growth. Second, this relation strengthens as we move from the initial estimates of economic activity to more recent vintages, which are closer to the true state of the U.S. economy. Third, our real-time index of VMT growth has incremental predictive content for the revisions in the initial estimates of employment growth and real GDP growth. Fourth, our analysis of the granular origins of aggregate VMT fluctuations shows that the index of aggregate VMT growth can be constructed in a cost-effective way by focusing on a subset of key states. Indeed, we find evidence of diminishing marginal benefits from adding more states in the aggregation process beyond the top-10 states in terms of contribution to aggregate VMT. Our analysis of the granular origins of aggregate VMT fluctuations also highlights the importance of state of California for gauging fluctuations at the federal level. Indeed, we find that on a stand-alone basis California VMT growth explains as much as 64% of the time-series variability of aggregate VMT growth. This result is striking given that California VMT accounts for 11% of the aggregate VMT level.

Our findings have important implications for a wide array of decision makers, including the Federal Reserve when formulating monetary policy, the White House when setting the Federal Budget, businesses when making investment decisions, and capital market participants when setting asset prices. Our findings can inform the BEA of the U.S. Department of Commerce and the Bureau of Labor Statistics when measuring the U.S. economy. We believe that our report will serve as the starting point for several follow-up studies on the interplay of VMT and economic activity both at the federal and at the state level.

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