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Perspective

Planning, climate change, and transportation: Thoughts on policy analysis

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1. Introduction

According to Jim Hightower, a politician, writer, and commentator, there is nothing in the middle of the road but yellow stripes and dead armadillos. Despite that commonsense warning, my comments are partly intended to find the middle ground that is supported by theory and empirical evidence. More importantly, I write to clarify concepts that were unclear or misused in the articles by Moore, Staley and Poole (this issue, hereafter MSP) and Winkelman and Bishins (this issue, hereafter WB). In so doing, I offer insights into what research and planning can contribute to the climate change – transportation policy debate.

MSP and WB disagree on three key issues. MSP prefer market-based regulatory mechanisms, primarily prices, while WB prefer land use and alternatives to the automobile. MSP and WB differ dramatically in their cost assessments, with each essentially reversing the other's ranking of the cost effectiveness of different policy options. Most fundamentally, MSP and WB disagree about vehicle miles of travel (VMT). MSP view VMT as a necessary concomitant of economic growth, while WB view VMT reduction as a desirable goal almost in and of itself. To address these disagreements, I organize this paper around four questions. First, what is the policy objective? Is reducing VMT the appropriate end target? Second, what theoretical insights are important in the debate between MSP and WB? Third, what does the evidence say? Fourth, what should policy-makers do?

Before I go further, let me state some conclusions up front. Externalities from greenhouse gas emissions will and should be one of the most important considerations in transportation policy in the decades ahead. The most effective policy responses will combine pricing and land use regulation. There is a large body of evidence that land use policy can reduce automobile use, and hence vehicle miles of travel. The magnitude of the land use – travel behavior relationship appears to be small in the near-term but can cumulate over time if sustained land use and transportation investment policies support less auto-oriented urban development patterns. The magnitude of the land use – travel link likely varies substantially across places in ways that are still obscured by the fact that much of what we know about land use and travel is a statement of broad regional averages. This brings us to the inherently planning-oriented nature of the land use – transportation – climate change discussion. Local context will matter. What makes sense for some places may not make any sense for others. To speak broadly risks ignoring the distinctiveness of places and the need for context sensitive planning. Of course, such planning requires a foundation, and so I turn to the details that should underpin policy discussion on this topic.

2. The policy goal

The papers by MSP and WB debate whether reducing vehicle miles of travel (VMT) is an appropriate focus for greenhouse gas (GHG) emission policy. Conceptually, the externality should be the policy target. Externalities are side effects of

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otherwise useful economic transactions. In this case, driving (and hence VMT) produces GHG emissions which create harm from climate change.[1] For many production processes, reducing the externality entails reducing the associated economically useful activity.

WB seem to argue that there are many externalities from driving and many co-benefits from reducing driving. Yes, there are externalities from driving (congestion, criteria pollutants, accidents) and possible co-benefits from reducing driving (largely falling under the rubric of community quality of life), but WB should better articulate those and focus their argument more clearly on the external costs and benefits. It is not VMT that is harmful but the negative external effects of driving (e.g. GHG emissions, criteria pollutants, congestion at bottleneck locations and times, accidents). Similarly, we should not seek to reduce VMT as a goal in itself, but there may be benefits from policies that while not targeting VMT, reduce VMT all the same (congestion fees, fuel taxes, emission fees, and a host of useful planning initiatives all would fall into that category).

MSP argue that we should focus only on the externality, but they overlook or under-appreciate the extent to which there will be a tight link between VMT and GHG emissions in the near term. With time, changes in vehicle technology, fleet composition, and fuels will weaken that link, as hybrid vehicles, plug-in hybrids, and possibly more exotic technologies penetrate the market. But as a practical matter, for the next several years GHG reduction from the transport sector will be based on conventional increases in vehicle fuel efficiency, reductions in the carbon content of fossil fuels, and reductions in VMT. Practical policy-making will have a role for VMT reduction, not because the goal is to reduce VMT *per se* but because VMT reduction will have a place in a suite of policies designed to reduce GHG emissions. On this count, MSP and WB talk past each other, failing to acknowledge the vital middle ground.

Partly the two papers talk past each other because both fail to grapple with the complexity of VMT. VMT is an externality-producing, economically useful activity. MSP talk a lot about the association between VMT and economic growth, and WB see externalities but not much else. Each is, in effect, focusing disproportionately on half of the story. Mobility, and hence VMT, is associated with economic growth. MSP focus on part of the story. Yet that does not logically imply that increased automobility should be accepted on any terms, and externality regulation has always entailed some restriction in otherwise useful economic activities. VMT, while not the externality *per se*, will as a practical matter be a sensible policy target, but only so long as policies recognize that it is GHG, not VMT, that is the climate change target. A key question, then, is making certain that policies that target VMT reduction maintain a focus on GHG emissions, using VMT only as a proxy rather than an end. Most policy-making with which I am familiar is quite focused on the GHG emissions goal, appropriately so. To suggest that policies are doing otherwise constructs a strawman (in the case of MSP.) To suggest that policies might usefully use VMT as the target (as WB at least loosely imply) aids those who would construct such strawman arguments.

3. Theory

The articles by MSP and WB illuminate three theoretical points that require clarification. Each is discussed below.

3.1. Land use and pricing are complements, not substitutes

MSP and WB reflect the caricatured nature of current policy debate, which has fragmented into advocates of pricing who see little (if any) role for land use, and advocates of land use who similarly ignore or minimize the role of pricing. Land use and pricing are complementary policy approaches. Basic economic theory suggests that goods are more elastically demanded when there are more close substitutes. For example, the consumers at a local restaurant will become more price sensitive if several nearby restaurants open up. The same principle holds for transportation policy. The impact of a GHG emission fee depends on the price elasticity of demand for driving.[2] If demand is more elastic, there will be more externality reduction for any level of fee. Equivalently, a lower fee is needed to attain fixed clean-up goals when the price elasticity is higher. Land use and infrastructure policies that create viable alternatives to car travel will increase the price elasticity of car travel. How much the elasticity would change is an empirical matter, but the theoretical point is that the "either/or" nature of the debate ignores the reality that both pricing and land use policies are mutually supportive.

Rodier (2009), in a review of travel model results from 24 metropolitan areas, gives insight into this complementarity. Rodier (2009) compared predicted reductions in vehicle kilometers of travel (VKT) or greenhouse gas emissions from business as usual scenarios after 10, 20, 30, and 40 years of sustained policy implementation. Policies were grouped by type – e.g.

[1] While MSP accept that the planet is warming, they express four reasons for doubting the need for near-term policy action. Briefly, MSP argue that (1) there is scientific uncertainty about the needed magnitude of reduced GHG emissions, (2) global temperatures have not warmed during the past decade, allowing a delay in policy action, (3) other countries produce the bulk of GHG emissions, and so the US cannot or should not act alone, and (4) in their last sentence they express some doubt about whether warming is anthropogenic. Much of this debate, e.g. about the meaning of 10 year temperature trends, is better fodder for journals that specialize in climate science. For the record, I accept that GHG's are an important human cause of climate change and that GHG emissions are a classic environmental externality requiring a policy response. I do not find MSP's arguments for delay to be compelling. The policy challenge is complex and will require decades of attention. In my opinion, reasoned, scientifically grounded efforts to reduce GHG emissions should be pursued now. I also disagree with MSP's contention that the US ought not act alone. I believe that local, state, and national policy-making can and should be an adjunct to international negotiations, and that the political complexities of both domestic and foreign policy suggest that progress should be made on either front when possible rather than waiting for a coordinated grand plan.

[2] This assumes that vehicle and fuel technology are fixed, which is a good approximation to reality in the short-term. The most likely medium-term change would be increased market penetration for hybrid or plug-in hybrid vehicles.

land use policies (higher density, infill development, and mixed land uses), increases in transit service and transit infrastructure, and VKT pricing. The exact policies likely varied in the different model applications, and if so the results do not compare exactly the same policies across the model runs, but impacts varied noticeably across the groups of policies. The median VKT reduction from land use policies was 0.5% after 10 years and 1.7% after 40 years. The median VKT reduction from VKT pricing was 9.9% after 10 years and 11.1% after 40 years. Land use policies combined with transit investments gave median VKT reductions of 3.9% after 10 years and 15.8% after 40 years. Combined land use, transit, and VKT pricing policies yielded median VKT reductions of 14.5% after 10 years and 24.1% after 40 years.[3] These are simulations from models of varying sophistication, so the magnitudes should not be taken as definitive, but rather are indicative of ballpark estimates and of the varying impact across different groups of policies. The combined policies, using land use, transit investment, and pricing, were substantially more impactful than single policies used alone. The pricing policies yielded larger individual impacts, and so were likely responsible for the larger portion of the combined impact, but more telling is the power of mutually supportive policies when used in combination. These estimates are from simulation models, which are only as good as the behavioral assumptions built into the models, and the forecasts are scenarios, not evidence from studies of past policies.[4] The point is that pricing and land use should, theoretically, be mutually supportive, and Rodier's summary of scenario forecasts supports that theoretical proposition.

3.2. Prices versus quantities as a regulatory instrument

MSP argue that optimally pricing the externality is the preferred solution. Yet Weitzman (1974) illustrated that in the presence of uncertainty, either price or quantity regulation may be optimal, depending on the nature of the uncertainty.[5] The uncertainties in climate change policy are substantial. The climate system itself has multiple feedback loops and thresholds, and our evidence on the behavioral impacts of policies is based on sample data that, while increasingly sophisticated, still is quite a bit shy of what would be desired (see, e.g., the data recommendations in National Research Council, 2009). While those uncertainties do not cast doubt on the basic proposition – GHG's are a cause of man-made change in the climate system – the question of prices versus quantities is not nearly so simple as MSP imply. A full comparison of the information criteria needed to conclude whether, in the broad, price or quantity regulation would be preferred for GHG reduction would be complex and is beyond the scope of this paper. But there are hints that emissions pricing, by itself, may not be a fruitful approach to GHG reduction in the transport sector.[6]

Sperling et al. (2009) illustrate the limits of relying only on pricing in the transport sector by comparing pricing policies for driving and for electricity generation. Sperling et al. (2009) conclude that a $25 per ton tax on CO2 emissions would increase the retail price of electricity by 20%. They argue that such a retail price increase would encourage shifts from fossil fuels to renewable power generation because there are many alternative electricity production technologies that are viable alternatives, and a 20% retail electricity price increase would create market incentives to shift some power generation to renewable sources in many locations. Driving is a different story. Sperling et al. (2009) calculate that doubling the hypothetical carbon tax to $50 per metric ton would increase gas prices by 45 cents per gallon.[7] They argue that such a price increase would do little to change fuel choices or driving behavior. The key is the low elasticity of gasoline consumption, and hence of driving, and one key to that is that there are no widely available alternatives to driving with conventional fuels in conventional vehicles.[8] Advocating price mechanisms while ignoring the lack of alternatives to current vehicles, fuels, and driving is naïve. A full menu of policies is needed. Such a menu should have a central role for market-based approaches, with GHG pricing as a key element. But for the transport sector, the effectiveness of pricing policies will be enhanced by and will likely require regulations that foster changes in vehicle technology, reductions in the carbon content of fuel, and land use – transportation planning efforts that provide alternatives to driving.

Admittedly, land use planning has played almost no role in reducing criteria pollutants (e.g. Howitt and Altshuler, 1999). Yet I believe planning should be in the mix for GHG regulation for several reasons. The climate change problem, based on the stock rather than the flow of the pollutant, will require decades of sustained policy activity. The fact that land use takes years to adjust was a disadvantage when the focus was on flow pollutants, but the long-term nature of a stock pollutant turns the common disadvantages of land use approaches (urban form is slow to adjust and difficult to reverse) into advantages. Second, the co-benefits from better land use planning can be substantial. The rapidly growing and already quite dense metro-

[3] All reductions are relative to "business as usual" scenarios – i.e. scenarios that represent a continuation of status quo policies.

[4] Simulation models use parameters and relationships that are estimated from empirical studies, and so there is some interplay between scenario forecast models and evaluations of past experience. The most sophisticated simulation models draw on intensive efforts to estimate underlying behavioral parameters from empirical data. Even so, building behavior into these models is one of the more challenging aspects of the endeavor, and many modelers would argue that the goal of scenario forecasts is not to test behavioral hypotheses but to compare alternative futures. Readers are cautioned that scenario forecasts are just that, model forecasts, and the quality of comparisons of alternative futures hinges on the success in incorporating behavioral responses into the forecast tool.

[5] I thank Randy Crane for suggesting this point.

[6] MSP acknowledge the same point, if implicitly, by focusing on a host of vehicle technology solutions. Yet MSP ignore the long history of government regulation requiring the adoption of emission reduction technologies in the transport sector, and instead imply that the private market would adopt such policies absent specific requirements to do so. That is counter to the historical experience of the past five decades.

[7] For perspective, 45 cents per gallon is smaller than the within-year retail gas price changes in each year from 2004 through 2009, based on data from the US Energy Information Administration at http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html.

[8] WB make essentially the same point using some of the same calculations.

politan areas of California are an example. In many locations in California, and in metropolitan areas in other US states, economically vibrant inner suburbs are experiencing substantial infill development pressure. That infill growth, in places designed almost exclusively for auto travel, is leading to increased arterial traffic congestion. The transportation challenge in many metropolitan areas includes building travel alternatives that act as safety valves that relieve what would be higher levels of street and arterial traffic congestion in the presence of the infill development that is occurring or will occur due to market pressure.[9] While this story does not describe Peoria, Illinois, it describes many parts of Southern California and the Bay Area and other large and growing urban areas. Land use planning and coordinated transportation investment, in the context of local needs, will be vital. The point is not that land use planning is the only or even the best instrument to reduce GHG emissions, but improved land use planning can be consistent with other environmental and community goals.

3.3. Flawed cost estimates

Both MSP and WB develop cost estimates. WB conclude that some land use initiatives (e.g. transit oriented developments or TODs, in particular) have negative cost. They do not argue that such projects are low cost, or that they are free, but that we get money back. Like tales of revenue increasing tax cuts or perpetual motion machines, these claims require a skeptical look.

WB dicuss cost savings that include leveraged private investment, reduced household transportation expenditures, and increased tax revenues. The private investment and associated tax revenues are classic examples of double counting benefits. The private investment near a TOD almost certainly would have gone elsewhere had the TOD never been built. For example, the ten-story office building near the TOD would have been near the freeway had the TOD not been built. With or without the TOD, the private investment and the tax revenues from that private investment still exist, they just exist in different places. Counting proximate private investment as a TOD benefit ignores the fact that the TOD influences the location of the private investment, but absent the TOD that private investment would usually go somewhere else.[10]

Household fuel consumption, another key part of WB's cost calculations, is only part of a valid measure of travel costs. Household or individual travel cost should be measured by the sum of time costs and out of pocket (or money) costs. It is impossible to know how the full cost of travel (time and money) changed if one only knows that fuel costs went down. Possibly time costs (i.e. travel time between particular origins and destinations) increased, or possibly other costs changed? In short, WB focus only on a part of individual or household travel costs, and on the part that is most likely favorable to their argument.

Turning to the specific examples in WB, the taxes from investment near the Atlantic Station TOD would likely have been realized on investment elsewhere had the TOD not been built. The avoided infrastructure costs cited from Sacramento do not illuminate what would happen to private investment. The Sacramento plan entails building infill on more expensive land, possibly with increased construction costs. On net, we simply do not know from the information in WB how either project would look in a comprehensive cost–benefit analysis, with benefits compared against reasonable counterfactual situations and measured in ways that do not double count and with external benefits carefully measured. Personally, I am a fan of both Atlantic Station and the Sacramento plan, but I do not find the WB cost estimates to be credible.

MSP develop cost estimates for four types of policies: (1) improved vehicle fuel economy, (2) traffic signal timing improvements, (3) Smart Growth land use policies, and (4) increases in the use of transit. They are able to quantify all of those except land use, and the basic results, showing that fuel economy and signal timing investment are relatively lower cost, are reasonable. Regarding land use, MSP note that the cost of land use policies depends importantly on how land use regulation affects on consumer choices. Certainly that is true, but MSP then argue rather strongly from exaggerated concerns about infringements on individual liberty. As an example, MSP state, "We must consider the radical transformation of living and traveling we would all have to undergo to achieve the VMT reduction necessary to dramatically reduce vehicle GHG emission." To be fair, they back this up by arguing that land use policies will require densities above 6000 or 7000 persons per square mile and they discuss transit trip capture rates in excess of 33%, both of which would be substantial changes for most metropolitan areas. Yet MSP set up a strawman, assuming that land use policies would necessarily force density levels needed for efficient mass transit, and force those everywhere.

As discussed later in this paper, the evidence on current building patterns suggests there is much scope for considerably more modest land use changes that would both reduce VMT (and hence GHG emissions) at the margin and likely deliver other benefits if the land use policies are part of sound planning efforts. To foreshadow that point, the changes that might be most impactful could involve reducing the amount of housing built on lots larger than an acre. Yes, that or any externality-reducing regulation will limit individual choice; that is a necessary element of any successful social-welfare-improving externality regulation, and the only question is whether choice is limited through prices, quantity restrictions, or technology mandates. But realizing that the development that might be constrained is, in important part, large-lot low density devel-

[9] For an example that discusses accommodating walking in auto-oriented suburbs, see Boarnet et al., 2011.

[10] The exception to this conclusion would be cases of increasing returns to scale. What if the TOD generated agglomeration benefits that did not otherwise exist? In such cases, there might be net increases in economic activity in the city, metropolitan area, or possibly even larger units of geography. While possible, most TOD and land use investments are at a scale that is smaller than what would likely create increasing returns. There is a large literature on double counting in transport economics. That literature suggests that an assumption of constant returns, and hence regarding private investment as location decisions rather than decisions about whether to invest, is by and large the best description of policy activity. See, e.g., Mohring and Harwitz (1962), Mohring (1993), and Boarnet (1997).

opment rather than efforts to eliminate single family housing or force Brooklyn-Queens densities changes the picture somewhat. More generally, the ideas envisioned by current policy proposals encourage integration of land use planning and transportation investment, leaving local governments to decide the best approach for their context. Realistically, this will mean choosing from a menu that will include things like sidewalk construction, parking management, congestion pricing, infill development, traffic operations improvement, alternatives to the automobile, and much more. Local governments retain robust land use authority even in regulatory regimes (such as in California) where GHG reduction has been pioneered. That, coupled with the fact that the goal of regulation is to match policies with context, suggests that concerns about dramatic changes or infringements on individual liberty are either overwrought or scare tactics.

One last point on economic theory: Toward the end of their article, MSP mention the Pareto criterion, common in economic analysis. In its simplest form, the Pareto criterion judges a policy change to be superior if it makes no person worse off while improving the welfare of at least one person. Yet in practice the Pareto criterion is always applied with a compensation principle – policies that produce welfare gains for the "winners" that are larger than the welfare losses that accrue to the "losers" are judged Pareto superior. This is because in concept the winners could compensate the losers fully and still be better off. The Pareto criterion with a compensation principle translates to classic cost–benefit analysis. While this is the stuff of analytic debates, the important point is that hardly any policy is really Pareto improving without invoking a concept of compensation or, equivalently, a cost–benefit test. If we analyzed the matter fully, we would likely find that the interstate highway program, the Apollo program, and the US defense budget all leave someone worse off, if for no other reason than some persons would not value the taxes required to fund those programs. Implying that climate change policy should somehow leave no person worse off is a radical statement, departing from cost–benefit analysis as it is typically practiced and seeking to invoke a pure form of the Pareto criterion without compensation, which is not realistic for practical policy-making.

4. Empirical evidence

There have been scores of studies of land use and travel behavior over the past two decades.[11] Here I focus strictly on the relationship between distance traveled (e.g. vehicle miles of travel) and land use.

Studies that use micro-data, with travel measured for individuals or households, are preferred to studies that aggregate data to broader geographic units. Micro-data avoids possible aggregation errors or ecological fallacies and allows for better causal inference. Such micro-data are drawn from travel diary surveys that track all trip-making for survey respondents for a small number of days (two days is common.) Most of those travel diary studies are for single metropolitan areas, which raises questions of generalizability beyond the study area. For that reason, studies that use national or (at least) statewide data sets are preferred. Studies should use a rich set of sociodemographic characteristics as control variables and should correct for the possible endogeneity of residential location choice. All these points are discussed in, e.g., Brownstone (2008).[12]

Selecting only studies based on micro-data from geographic settings larger than a metropolitan area, with a rich set of individual or household sociodemographic control variables, with sound econometric specifications and controls for residential self-selection or endogeneity of key variables more generally, leads to a small set of studies. Table 1 summarizes some of the best recent studies on vehicle miles of travel and land use. All of the studies in Table 1 meet the methological criteria discussed above (with the exception of Fang, 2008, who did not adjust for residential selection but who discussed the implications for her work). The studies are, with the exception of Fang, the same as those that inform the recent National Research Council report (NRC, 2009) *Driving and the Built Environment*.

The most common land use variable in these studies is density. A recent National Research Council report on the topic noted that for the relatively small number of studies that use micro-data from geographies larger than one metropolitan area with a rich set of sociodemographic controls and econometric methods to handle residential selection, the estimated elasticity of VMT with respect to density is in a range from 0.05 to 0.12 (NRC, 2009).[13,14] Other land use variables are in the same range; for example, Bento et al. (2005) found that the elasticity of VMT with respect to several measures of jobs-housing balance, population centrality, transit supply, and density, when considered singly, was typically less than 0.07. Density is at best a proxy variable for a large range of land use characteristics that are associated with travel, such as land use mix, the character of

[11] For recent literature reviews, see Badoe and Miller (2000), Boarnet and Crane (2001, chapter 3), Brownstone (2008), Crane (2000), Ewing and Cervero (2001), Handy (2005), and NRC (2009, chapter 3).

[12] Brownstone concludes that using these selection criteria, the impact of land use on vehicle miles of travel may be null. I disagree, noting that the best studies when judged by the same criteria, including a study by Brownstone and Golob (2009), give statistically significant impacts of land use on vehicle miles of travel, within a fairly tight range, as discussed below.

[13] Boarnet was on the study committee which authored the NRC (2009) report.

[14] Del Valle and Niemeier (2010), in a recent working paper, use data from the 2000–2001 California Statewide Household Travel Survey. Their study meets the criteria for inclusion in Table 1 – namely the data cover more than one metropolitan area and the econometrics control for residential selection and include a rich set of sociodemographic control variables. Del Valle and Niemeier (2010) find an elasticity of VMT with respect to density equal to 0.19, larger than the 0.05–0.12 range indicated by Table 1. Because the Del Valle and Niemeier (2010) study was still a working paper and had not completed the referee process at the time this paper was written, it is not included in Table 1. Note, though, that Del Valle and Niemeier (2010) suggest that their methods may reveal underestimations of the VMT-density elasticity in earlier studies of the sort in Table 1, although Del Valle and Neimeier (2010) note that even with an elasticity of 0.19 density alone cannot attain the GHG reduction envisioned in the California Air Resources Board (2008) scoping plan for the state's broader GHG policy effort.

Table 1
Elasticity of VMT with respect to land use: results from studies of individual or household travel. *Source*: Adapted from NRC (2009), with addition of Fang (2008).

Study	Built environment feature	Geographic location	Percent increase in built environment feature	Percent reduction in VMT	Elasticity (all are negative; magnitudes are shown)
Measures of the effect of changing one built environment variable alone, holding others constant					
Bento et al. (2005)	City shape, jobs-housing balance, road density, rail supply (for rail cities) – each variable alone	114 US MSA's	100	⩽7	⩽0.07
Bento et al. (2005)	Population Centrality Alone	114 US MSA's (without New York)	100	15	0.15
Brownstone and Golob (2009)	Population density	California	100	12	0.12
Fang (2008)	Population density	California	100	8–9	0.08–0.09
Measures of the joint effect of changing multiple built environment variables					
Bento et al. (2005)	All built environment variables	Compared predicted VMT for identical residents in Atlanta, GA and Boston, MA, using regression results from 114 US MSA's	n/a	25	n/a

Note: regarding the Bento et al. (2005) Atlanta-to-Boston comparison, Bento et al. (2005) report land use variables for Atlanta and Boston in their Table 6 (p. 477). Values for the key variables are typically doubled or less across those two cities, with the exception of city shape, which is about three times larger in Boston. Higher values of "city shape" indicate more circular cities, hence Boston is more circular. The NRC (2009) report used the Bento et al. (2005) result in combination with earlier meta-analyses by Ewing and Cervero (2001) to assume that an elasticity of 0.25 is a likely upper bound for the impact of all built environment factors combined on VMT. Here I do not convert the Bento et al. (2005) result to an elasticity, but such a conversion to an elasticity of 0.25 is likely approximately correct based on the values of the land use variables reported in Bento et al. (2005).

the street network, access 0074o employment, shopping, and service destinations, and both road and transit infrastructure. Those variables may work synergistically, implying that the impact of land use change (which typically involves changing several variables at once) may be larger than the impact of any one variable considered singly. Bento et al. (2005) gives insight by modeling the change in predicted VMT for identical persons living in the Atlanta, Georgia and Boston, Massachusetts metropolitan areas. VMT is predicted from the results of land use – travel regressions on 114 metropolitan statistical areas, using travel diary data from the 1990 Nationwide Personal Transportation Survey. Bento et al. (2005) found that predicted VMT was 25% lower in Boston than in Atlanta, suggesting that the impact of changing several land use variables jointly is larger than the impact of changing those variables singly.

NRC (2009) simulated the role that land use might have on greenhouse gas emission reductions relative to "business as usual" scenarios from the present to 2030 and 2050. If 25% of anticipated new residential development is built at twice the current density of new development, and using only elasticities in the 0.05–0.12 range (hence ignoring any synergistic effect of multiple land use characteristics that may be associated with density), land use – travel impacts would lead to less than a 2% reduction in GHG in both 2030 and 2050 relative to business as usual – a small impact indeed. If 75% of new residential development was built at twice the current density of new development, and assuming an elasticity of 0.25 to account for multiple built environment characteristics at once, land use would result in as much as an 11% reduction from business as usual GHG emissions in 2050.

What would the assumed density changes mean? Doubling the density of new development implies building in a density range that is between 2 and 3.9 dwelling units (du) per acre, as opposed to 1990–2000 new development densities of 1–1.9 du/acre.[15] From 1990 to 2000, 47.5% of all new housing built in the US was in tracts with densities less than 1 du/acre. Admittedly this is in part because those tracts were in the process of filling up, but the data also suggest a substantial amount of large lot (e.g. one to two acre) building. Doubling the density of 25% of new development could have been achieved, from 1990 to 2000, if half of the housing units built in census tracts with densities below 1 du/acre were diverted to higher density tracks, in proportion to the existing distribution of housing in those tracts. Thirty-nine percent of that diverted housing stock would have been built in tracts with average densities in the range of 1–2 du/acre. The point is that there is a large middle ground that allows for reductions in the density of new development, and while doubling the density of 25% of new development is a departure from national trends, arguments that such departures would be draconian moves away from single family housing do not square with the facts. Doubling the density of 75% of new development is more aggressive, and the political feasibility of that approach is open to debate and disagreement, even among members of the authoring committee of NRC (2009).

The built environment adapts slowly over time, and changes from land use will require sustained policy direction over several decades. Land use is not a panacea, but can be part of a long-term solution several decades into the future. Those who wish to ignore land use entirely ignore the long-term nature of the climate change problem, which will require a series of policies that will deliver results successively over several decades. Land use can be part of that policy portfolio. Yet those

[15] The range is because density is measured two ways in NRC (2009). One density measure corresponds to the average density of a new acre, and the other measure corresponds to the average density of a new dwelling unit. See NRC (2009, Appendix B) for a discussion.

who argue that land use is the single best solution, or that land use impacts will be large in the near-term, overstate the evidence. While the evidence suggests moderation, the literature as it has evolved and grown more sophisticated gives consistent evidence that land use has an impact on travel behavior.

The evidence on land use and travel has methodological shortcomings which require future attention. A key issue is the role of thresholds.[16] The evidence, as summarized in Table 1, is average effects from large data sets for either one state or the entire US Those averages likely obscure substantial variation in the effect of land use on VMT in different land use settings. Focusing on much smaller geographies gives hints that average impacts across regions may obscure substantial within-region variation. For example, Boarnet et al. (2011) analyzed 2125 travel diary surveys in eight small (approximately 1/2 mile radius) neighborhoods in Los Angeles County. For comparison, this sample size is approximately the same as the NHTS California subsample used by Fang (2008). Boarnet et al. (2011) found substantial travel behavior variations even within their relatively small study neighborhoods. For one neighborhood and controlling for household characteristics, residents within 1/4 mile of a commercial concentration averaged five times more walking trips and 25% fewer driving trips than persons in the balance of the same neighborhood, all of whom were within a mile of the same commercial concentration. Those magnitudes are considerably larger than much of the literature.[17] While those results cannot scale to the region, they hint that the average land use – travel estimates in the literature obscure possibly broad variation in impacts and effect sizes in different geographies. While an earlier literature on transit focused on identifying density thresholds associated with ridership (e.g. Pushkarev and Zupan, 1977), there has been little focus on the question of thresholds in relation to driving. Yet such knowledge will be necessary to identify what land use changes might most fruitfully influence changes in VMT and associated GHG emissions.

5. Lessons for policy

Ideally, policy should be informed by social welfare analyses that carefully assess costs and benefits. In the context of GHG policies, such analyses face particular challenges. The decades-long span of GHG policy-making will require introduction of new technologies, some foreseeable, some not. While current models can give estimates of economic costs and benefits, all current models are fragile when trying to assess changes in production that span decades and that involve to some extent unforeseen economic transformations and new technologies. MSP and WB both give examples of approaches to costs and benefits that are common in the debate, emphasizing estimates that reflect advocacy positions. We should design policies in light of the empirical results (which are broadly consistent in terms of direction of impact and relative magnitudes) and monitor, learn, and refine. Costs and benefits should be carefully measured, but such measurements will inherently be uncertain. Flexible policy tools that take advantage of market mechanisms should be preferred.

What role, then, for land use? Two points are important. First, land use and pricing are mutually supportive, but the near-term impact of pricing policies is larger. Second, land use policy is about city-building. Planning is place-making through democratic governance. Aggregating opinions about "the good community" – the fundamental planning task – will always require debates about aesthetics and preferences for different living patterns. The land use – travel element of GHG policies will be caught up in such debates, as is appropriate. The point is to recognize that community building is not solely about narrow questions of GHG emissions or other instrumentalist goals, but also about building neighborhoods and cities that thrive.[18]

In this context, California's approach is promising. Senate Bill (SB) 375, enacted into law in 2008, defines the land use elements of the state's GHG emission reduction policy. SB 375 requires that the California Air Resources Board develop transport-sector GHG emission targets for the state's 18 metropolitan planning organizations (MPO's), and MPOs will then have to certify that their regional transportation plans (which are programs of infrastructure investment) are consistent with meeting the targets. While land use authority is the domain of municipal governments, not MPOs, the legislation also hopes to encourage land use change that will be coordinated with alternatives to automobile travel.[19]

The evolving SB 375 policy framework will be distinctly multi-level in nature. The state government will set and monitor MPO targets. MPOs, in turn, are composed of municipal governments, and the actions of the municipal governments will influence MPO regional transportation plans. MPOs can meet their targets in a variety of ways, and in turn regional transportation investment and land use policy will vary from municipality to municipality within an MPO. Far from being

[16] The most commonly mentioned methodological issue in these studies is endogeneity of land use variables due to residential selection. That is not relevant for Table 1, which with the exception of Fang (2008) and NRC (2009) shows impacts from high quality studies that control for self-selection. Cao et al. (2009) reviewed 38 land use – travel studies that attempted to correct for residential self-selection. They found that in virtually all cases the role of built environment factors remained after controlling for residential self-selection, although there remains some question about how much of the net effect is directly from land use and how much is residential selection.

[17] Using data in Boarnet et al. (2011), the results from the neighborhood in question, Artesia Boulevard, imply an approximate 25% decrease in car trip generation rates across two locations where housing unit density differs by about 50%. This cannot be converted into an elasticity that can be compared to the literature, as density was not included directly in the regression. (See Boarnet et al., 2011, for an explanation of the comparison of travel within the Artesia Boulevard neighborhood.) But the magnitude is larger than in the literature on regional impacts. As a comparison, trip generation elasticities with respect to population density in the more regional-level studies reviewed in Ewing and Cervero (2001) are never larger than 0.15 in magnitude.

[18] On this point, see Boarnet and Takahashi (2010).

[19] For background on SB 375, see Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375, A Report to the California Air Resources Board, 2009, available at http://www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf. Also see Stivers (2008) and California Air Resources Board (2008).

a "density forcing" policy, SB 375 has the promise of allowing a broad range of experimentation and policy innovation, allowing local governments to choose tools that fit their context. Successful land use planning requires such a decentralized, context sensitive approach.

The empirical evidence provides some clues about fruitful policy approaches. SB 375 will be most effective if pricing is incentivized and rewarded. The empirical evidence suggests that the elasticity of VMT with respect to pricing is larger than the elasticity of VMT with respect to many land use tools. The specific pricing approaches (link pricing, cordon pricing, GHG emission fees, fuel taxes, parking charges, or the like) should sensibly vary across locations. Yet anything that could be done to encourage governments to better price the external effects of driving – always politically difficult – would be wise. Land use and transportation infrastructure investment should and can be coordinated with pricing. Regional transportation infrastructure investments are the primary policy target of SB 375, through the regional transportation plan. Coordinating such investments with pricing and land use will produce larger effects than pursuing infrastructure investment, pricing, or land use policies in isolation. SB 375, with its focus on targets and local implementation, has the promise of encouraging local innovation that matches policies to context.

MSP and WB both argue for overly simplified approaches, but both have insights that are important. MSP note that pricing has been overlooked in transportation for too many decades. While pricing is not nearly the panacea that MSP suggest, all the evidence that we have suggests that metropolitan transportation planning aimed at reducing GHG emissions should have a prominent role for pricing. WB are correct in arguing for the possibilities from improved land use – transportation coordination. Coordinating land use policies with transportation investment has rarely been tried at the metropolitan level in the US, and when it has, as in Portland, Oregon or the Rosslyn-Ballston corridor in Arglington, Virginia, the results are quite promising (see, e.g., Cervero, 2009). The next step is for state and federal policy to provide incentives to achieve GHG reduction goals from transportation, seeding hundreds if not thousands of local policy experiments that should be monitored and evaluated. California's SB 375 has the potential to evolve into such a policy framework. I believe the most fruitful policies will combine prices and land use, in ways tailored to local context and the desires of local residents. If that places me in the middle of the road, I hope my fate is better than that of the proverbial armadillo.

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