POLICY BRIEF

Gas taxes, distance-based charges, and transportation network company charges

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Project Description

This project reviews and summarizes empirical evidence for a selection of transportation and land use policies, infrastructure investments, demand management programs, and pricing policies for reducing vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions. The project explicitly considers social equity (fairness that accounts for differences in opportunity) and justice (equity of social systems) for the strategies and their outcomes. Each brief identifies the best available evidence in the peer-reviewed academic literature and has detailed discussions of study selection and methodological issues.

VMT and GHG emissions reduction is shown by effect size, defined as the amount of change in VMT (or other measures of travel behavior) per unit of the strategy, e.g., a unit increase in density. Effect sizes can be used to predict the outcome of a proposed policy or strategy. They can be in absolute terms (e.g., VMT reduced), but are more commonly in relative terms (e.g., percent VMT reduced). Relative effect sizes are often reported as the percent change in the outcome divided by the percent change in the strategy, also called an elasticity.

Summary

Strategy Description

Gas taxes, distance-based charges, and transport network companies (TNC) charges are all types of fees that affect the overall cost of driving. The gas tax is a well-established charge that applies uniformly when people buy gas. Distance-based or vehicle miles traveled (VMT) charges have been proposed as an alternative to gas taxes to more equitably charge road users as high-efficiency hybrids and full-electric vehicles mean an increasing share of drivers pay little to no gas taxes. Distance-based charges (DBC) are levied on vehicles based on the number of miles driven on public roads. While a DBC primarily aims to substitute for gas taxes, it can also serve as a congestion charge and more directly influence how much people drive. No existing TNC charges target distance traveled. Existing TNC charges are primarily revenue-generating, but some cities have implemented congestion charging for TNCs.

Behavioral Effect Size

Research on the effects of changing gas prices focuses on gas consumption and VMT. The research shows that a 10% increase in gas prices leads to a 2% to 3% decrease in gas consumption and a 10% increase in the cost of driving per mile (linked to gas prices) leads to a 1% to 1.5% decrease in VMT. There is, however, disagreement about whether changes in the gas tax, a more relevant analog to DBC, have a similar effect or a much stronger effect than changes due to market fluctuations. The limited research on the effect of DBC suggests that a 10% increase in the charge results in a 1% to 2% decrease in VMT. Research on TNC charges is

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also limited and suggests that a 10% increase in congestion fees for TNCs is associated with 4.8% decrease in the number of trips within the congestion fee area.

Strategy Extent

Gas taxes apply nationally with some variation between states and local governments. Similarly, proposed DBC and existing TNC fees apply at the state level with some local variation. The diversity of vehicle types and the conditions in which people drive mean that the effect of gas prices and other forms of charges on VMT varies systematically across contexts, notably in rural areas.

Strategy Synergy

The main source of synergy comes from the pairing of a DBC or TNC fee with a congestion pricing structure. This expands the purpose of DBC to include travel demand management and pollution reduction.

Equity Effects

Lower-income drivers pay a greater share of their income in gas taxes despite driving less. They are also more responsive to increases in the cost of driving, which can result in the cutting of essential travel. In the absence of redistribution programs or an income-based fee structure for DBC, the regressive nature of gas taxes persists with the switch. TNC charges have complex equity effects that can affect users and drivers. Charges that are allowed to vary by time of day, location, and pooling rides are more likely to put most of the burden on higher-income locations.

Strategy Description

Gax taxes

Gas taxes are the most comprehensive form of road user charging in the United States. All users who buy gas pay a share of the cost in the form of a tax that typically serves primarily to fund transportation infrastructure.

The gas tax's original purpose – largely to support infrastructure maintenance and expansion – meant that the tax rate was set based on funding needs rather than to influence how much people drive. However, the federal gas tax rate has remained unchanged since 1993, while in California, it was only indexed to inflation starting in 2020. Combined with the increasing share of hybrid and electric vehicles, gas tax revenue has stagnated, leading to funding gaps for transportation infrastructure that are expected to widen.

Distance-based road user charging

While no distance-based charge exists outside a few European countries that have programs for heavy-duty vehicles (see road charge brief), an increasing number of US states are either exploring distance-based charging or have implemented pilot programs. Oregon and Utah are the only states to have legislated some form of voluntary distance-based charges whereby drivers can sign up to pay a road charge in lieu of the state gas taxes (see, e.g., McMullen et al., 2016).

Existing programs aim primarily to use DBC as a complement and eventual replacement to the gas tax. Designing DBC to generate revenues for transportation infrastructure means that there is little current focus on travel demand management (and even an incentive to keep demand high to maintain revenues in the absence of alternative funding streams). Yet, one of the principal benefits of DBC is the ability to tailor the charge to different goals (Agrawal et al. 2023). The charge can integrate congestion pricing (e.g., charging more when driving within a designated area) or as an emissions-reduction tool (e.g., charging higher rates for more polluting vehicles).

Distance-based charging is appealing because it can serve multiple purposes, but this versatility comes with some concerns. For example, levying the fee relies on measuring accurately the distance people drive, which has given rise to privacy concerns when on-board technology is used, and equity concerns given that a flat fee is likely to be regressive.

Transportation Network Company Charges

TNC charges are widely used in the United States, but very few target congestion, and none aim to directly reduce the VMT contribution of TNCs, such as through deadheading reductions (Fuller et al., 2021). Most charges apply to all rides equally as a percent of the ride cost, or as a per-ride flat fee, and in some cases, the tax is on TNC's overall revenue (Lehe et al., 2021). Chicago, New York, and San Francisco impose an additional fee for trips taking place in the most congested areas of the city. Another variant of TNC charges that addresses VMT reduction when cities and states provide discounts to riders for shared rides, which can significantly reduce VMT (Santi et al., 2014).

Strategy Effects

Behavioral Effect Size

There is an extensive body of literature that examines the effect of changing gas prices on gas consumption and travel demand. Estimates vary widely depending on the outcome (gas consumption or travel demand), the measure of travel cost (gas price, driving cost per mile, or fuel efficiency of the vehicle), statistical methodology, and factors ranging from income, rural or urban residence, type and number of vehicles, and other household characteristics.

We focus here on two sets of studies. The first uses gas consumption as the outcome of interest (Table 1). While this outcome is not directly related to VMT, it is the only one where researchers have evaluated the effect of changes in taxation levels, the closest analog for a DBC. The second set of studies examines the effect of changing gas prices on VMT (Table 2). These studies are more relevant to VMT, but do not separate the effect of market fluctuations in gas prices from changes in gas tax.

Gas price and gas consumption

The effect of a 10% increase in the price of gas is generally associated with a 3% decrease in gas consumption. However, there is disagreement about the effect of changing the price of gas with taxes. Some researchers estimate a large effect, three to four times larger than a market-driven change in price of gas (Li et al., 2014), while others find no difference (Killian & Zhou, 2022).

Recent estimates of the elasticity of gas consumption with respect to gas prices are higher than previously found (e.g., Hymel et al. (2010) found elasticities near zero). Levin et al. (2016) attribute this difference to the quality of the data and the level of aggregation. They show that using more aggregated data, as did most older studies, leads to an upward bias (towards zero) in the estimates. The elasticity of -0.3 is supported by other recent work (Killian & Zhou, 2022). Upward bias can also appear when the estimate does not consider the anticipation of a price change. Coglianese et al. (2017) focus on this specific issue and find an elasticity in the -0.3 range.

Methodological issues are also at the core of the disagreement regarding the effect of gas taxes. Several papers find that the gas tax element of gas prices affects consumption differently and more strongly (Li et al., 2014; see also Lawley and Thivierge, 2018; Tiezzi and Verde, 2017). These studies find that increases in taxes linked to gas prices lead to a decline in consumption 3 to 4 times larger than an equivalent increase due to market fluctuations. They attribute the stronger response to how the tax increase is covered by media, the perception that tax increases are permanent (Li et al., 2014), and the ability to switch to more efficient cars in the long run (Tiezzi and Verde, 2017). However, Coglianese et al. (2017) and

Kilian and Zhou (2022) find no evidence that consumers respond differently. Both studies attribute the difference to the anticipation effect that comes from tax increases being announced in advance.

Gas price and VMT

The ability to switch to a more efficient car means that reduced gas consumption does not always translate to lower VMT. Research on car switching in the short-term (for households who own more than one car) is ambiguous. US-based research did not find conclusive evidence of car-switching (Burra et al., 2023), but a study in Denmark using more exhaustive data found that switching was an important strategy in multi-car households (De Borger et al., 2016). Gillingham (2014) shows that wealthy households in rural areas have the largest decline in VMT per vehicle, attributing the decrease to the ability to switch vehicles. This result contrasts the near-inelastic relationship in rural counties, reflecting a lack of alternatives to driving for most households there. The positive elasticity of driving with respect to gas prices for highly efficient cars provides further, if indirect, evidence that households may reallocate VMT to their most efficient car when gas prices increase (Knittel & Sandler, 2018; Wenzel & Fujita, 2018).

Conversely, lower-income households for whom substitution between vehicles is not an option may cut VMT more permanently and have larger negative elasticity even in the long term (given that prices remain elevated). In urban areas, this is facilitated by access to transit (Gillingham, 2014).

The variation in the miles driven depending on vehicle efficiency has led researchers to use cost (as measured by gas price) per mile driven when estimating the elasticity of VMT with respect to gas prices. Wenzel and Fujita (2018) find that using the cost of driving yields a significantly higher elasticity of -0.16 compared to -0.09 for gas prices. Langer et al. (2017) find no significant effect of gas prices alone on VMT, but a -0.15 average elasticity for the cost of driving. However, a meta-analysis finds little difference between the two metrics (Dimotropoulos et al., 2018).

Some estimates, like Gillingham (2014), are higher than the average elasticity with respect to gas prices (-0.22 vs. -0.1 from other studies). Other than differences in estimation method and data (vehicle- vs state-level), the Gillingham suggests that elasticities with respect to gas prices are sensitive to the macroeconomic context. The overall health of the economy (e.g., unemployment rate) affects people's income and ability to internalize fluctuations in the cost of driving (Killian and Zhou, 2022). Goetzke and Vance (2021) explicitly test how elasticity changes in different macroeconomic contexts by estimating the effect of gas prices on VMT in 2009 and 2017. They find that the elasticity of VMT increased from a low -0.05 in 2009 to an elasticity of -0.3 in 2017.

Table 1. Impact of gas taxes and gas price on gas consumption

Study	Study location	Study years	Measure of cost	Results
Levin et al. (2016)	243 cities in the United States	2006-2009	Gas prices	-0.27 to -0.35
Coglianese et al. (2017)	National state-level data	1989-2008	Gas price	-0.37
Li et al. (2014)	National state level data	1966-2008	Market price changes/ elasticity due to tax changes	Market: -0.113 / tax: -0.292
Kilian and Zhou (2022)	State-level gas consumption	1989-2022	Oil cost pass-through (instrument)	Gas: -0.31

Table 2. Impact of gas price on VMT

Study	Study location and data	Study years	Measure of cost	Results
Gillingham (2014)	California smog inspection data	2001-2010	Gas prices	0.22 reduction in VMT over two years
Goetzke and Vance (2021)	NHTS	2009 and 2017	Gas prices	0.05 reduction in 2009 and 0.3 reduction in VMT in 2017
Langer et al. (2017)	Ohio insurance monitor	2009-2011	Cost of driving per mile	0.15 average reduction in VMT
Knittel and Sandler (2018)	California smog inspection data and household demographics	1996-2010	Cost of driving per mile	0.15 average reduction in VMT
Wenzel and Fujita (2018)	Texas yearly emissions inspections	2005-2010	Cost of driving per mile (CPM) & and gas prices	CPM: 0.16 reduction in VMT Gas: 0.09 reduction in VMT
Dimitropoulos et al. (2018)	Meta-analysis of 74 studies, including international	1950-2017	Cost of driving	Weighted average is 0.1 to 0.12 reduction in VMT

Notes: All results refer to VMT reduction per vehicle in the short-run unless otherwise indicated.

Distance-based pricing and VMT

The lack of full-scale distance-based programs and the pilots' primary aim to evaluate the feasibility of using such a charge to replace gas taxes means there is a dearth of studies evaluating the impact of distance-based charges on VMT. The evidence that exists comes from a small set of pilot programs that included a congestion pricing module or an incentive to decrease driving overall (see Table 3).

The gas tax is an appropriate analog for DBC, but there are important differences. A flat DBC (equivalent to a gas tax) is fuel efficiency and source-neutral, and fee collection for a DBC is more burdensome and intrusive when the responsibility to report is on the user. These differences would likely affect how people respond to a change in the charge rate.

The congestion pricing program in Oregon found a 22% decrease in VMT when users had to pay the equivalent of eight times the gas tax as a fee per mile in downtown Portland during peak congestion hours and people living within four blocks of transit reduced their driving in the congestion area by 0.7 miles per day on average (Whitty, 2007). Small-scale experiments in the Puget Sound Region and in Melbourne found elasticities ranging from 1.3% to 1.8% reduction in VMT in response to a 10% increase in the fee per mile (PSRC, 2005; Martin and Thornton, 2017). Both experiments allocated a travel budget to households based on how much they typically drove. The users would then be charged a fee per mile driven and the total would be deducted from their budget. The participants kept any balance left in their budget at the end of the period. In Switzerland, Axhausen et al (2021) used a driving budget design but calculated the elasticity of total transportation cost, a measure that monetizes congestion and pollution costs. They found a higher elasticity of -0.31, meaning that a 10% increase in the fee per km led to a 3.1% decrease in the transportation cost users generated by driving.

Transportation Network Company pricing and trip volume

There is little research on the effects of TNC charges because 1) the charges are recent (the oldest one of any kind is from 2013) and many were rolled out just before the COVID-19 pandemic disrupted overall travel demand, 2) data from TNC is private and difficult to obtain, and 3) the charges are primarily for revenue generation and are too low to influence travel behavior (Fuller et al. 2021). TNC charges are further complicated by the platforms' own pricing algorithms, which already create a form of congestion pricing by adjusting prices based on demand and supply (Li et al., 2021).

Research on TNC charges fits into two categories (Table 4). The release of TNC data mandated by Chicago in 2019 has enabled some evaluations of the congestion pricing structure there. The second type of research relies on travel demand models to simulate the effects of different types of fees. In all cases, the outcome is the number of trips, sometimes disaggregated between solo and pooled trips. There is no empirical research on VMT reduction.

Research on Chicago found a price elasticity of TNC trips of -0.48 suggesting that a doubling of the price of a trip would result in a 48% reduction in the number of trips (Zheng et al., 2023). The Chicago congestion fee succeeded in increasing pooled rides by 16.4% (albeit from a lower base), decreasing solo trips by 11%, and all trips in the downtown area by 7.1%.

Research based on market equilibrium models shows that TNC charges have a limited impact on the number of vehicles in operation when paired with the kind of minimum wage guarantees in place in California, but that a time-based charge is more effective for decreasing congestion because it reduces deadheading (Li et al., 2021).

Table 3. Impact of distance-based pricing on traffic volume

Study	Study location	Study years	Vehicle type	Results
Axhausen et al. (2021)	3,700 participants in Switzerland	2019-2020	Passenger cars	-0.31 (total transportation cost)
PSRC (2005)	275 households in the Puget Sound region	2005	Passenger cars	-0.18 elasticity of VMT
Martin and Thornton (2017)	1,400 participants in Melbourne, Australia	2015-2016	Passenger cars	-0.13 elasticity of VMT
Whitty (2007)	207 participants in Oregon pilot program	2006	Passenger cars	22% decrease in VMT for eightfold increase in the gas tax rate

Table 4. Impact of TNC tax or fee on number of trips

Study	Study location	Study years	Vehicle type	Results
Abkarian et al. (2023)	53 million TNC trips in Chicago	Nov. 2018 and March 2020	TNC	Increase of 3.8 percentage point when price difference between shared and solo rides is $1.75
Zheng et al. (2023)	TNC trips in Chicago	Nov. 2018 and March 2020	TNC	4.8% reduction in the number of trips after 10% increase in fees
Li et al. (2021)	Simulated data based on San Francisco data	2016	TNC	Average 10% decrease in trips within congested area after $3 one-way cordon imposed

Extent

Gas taxes, while they vary by location, are universally applied to gas retail sales. Revenue collection is cheap and reliable, but revenues have been declining due to increases in fuel efficiency and the uptick in the adoption of alternative fuel vehicles.

The effect of changes in gas prices on VMT and gas consumption varies significantly across contexts. Drivers are more sensitive to price changes in the most rural and densest urban areas (Langer et al., 2018) and the further they are from the center of a metropolitan area (Spiller et al. 2017). The VMT elasticity with respect to gas prices also varies by region. Langer et al. (2018) tested this hypothesis by replicating the model Gillingham (2014, 2015) used in California and Pennsylvania and found that elasticity in Texas was lower. In a similar exercise, Gillingham and Munk-Nielsen (2019) show that the higher elasticity in Denmark can be reconciled with US levels when accounting for the distribution of commute distances or lower access to transit, suggesting that high access to transit significantly affects responsiveness to gas prices.

The technology for distance-based charging imposes no geographic limit but is constrained by political boundaries and private road networks. One of the critical components of all programs states have spearheaded is that the technology be able to charge out-of-state drivers who have not opted into the program or may not have the technology to track miles driven. Evaluations of existing technical solutions have adequately addressed this issue. The viable systems for road-user charging include the ability to distinguish between types of roads (public, private, tribal), and political boundaries. Despite technology being available, cross-boundary travel is likely to create loopholes that states may address with alternative technologies such as license plate readers.

There are significant upfront costs to implementing DBC depending on the chosen technology. Once the technology is established and deployed at scale, however, revenue generation can become far more efficient than a gas tax thanks to the greater adaptability of a distance-based charge.

Distance-based charging is more technically challenging than other forms of road charging, but some of the preferred technologies require little change to infrastructure and can be rolled out progressively. The main sources of delay are more likely to be institutional and political. The versatility of distance-based charging means that the technology can have a complex pricing structure that multiplies the potential for delays (Agrawal et al., 2023). For example, income-based or status-based (e.g., over 65 years old) discounts are best applied when linked to administrative data, which requires additional steps to protect privacy. Existing rules regulating gas taxes are likely to impose a gradual implementation of distance-based charging as some gas taxes have legislated time lines (e.g., Washington state). The novelty of the program in contrast to the well-established gas tax is likely to meet with resistance from users.

TNC taxes apply at the state and local level. Despite issues with reporting (e.g., Maryland, see Lehe, 2021), taxation is straightforward and can generate substantial income at little cost. Most taxations use a per-trip structure so that implementation is simple and rapid. There is too little data available to reliably establish if taxes have differential effects by region or in different contexts.

Equity

Gas taxes are regressive. Lower-income drivers pay more of their income in gas taxes despite driving less (Glaeser et al., 2023). Lower-income drivers and lower-income locations are also more responsive to increases in the cost of driving (Kilian & Zhou, 2022; Langer, 2018). Upper-income drivers also reduce their driving, but, in contrast to lower-income drivers, they cut excess driving (e.g., leisure activities) rather than essential driving, underlining the greater burden increases in gas prices put on lower-income drivers (Wang & Chen, 2014).

These disparities are accentuated in rural areas where lower income often intersects with higher VMT in contexts where employment and service accessibility require additional driving (Langer et al, 2018). The disparities between urban and rural burdens can be exacerbated by differential pricing. The nature of supply chains and lack of competition can lead to significantly higher gas prices in rural areas.

The use of revenues, most of which fund infrastructure maintenance and expansion, does little to rectify the inequitable aspect of gas taxes or benefit households who do not own a car (Knittel & Sandler, 2018).

Distance-based charges, if structured to replace the gas tax, would reproduce the regressive nature of the tax. They would correct, however, for the growing share of drivers, disproportionately higher-income drivers, who pay little to no gas taxes because they drive high-efficiency hybrid or all-electric vehicles (Glaeser et al., 2023).

The primary appeal of a DBC for equity is the flexibility of the fee structure. The DBC is tied to the driver meaning that the charge can be tailored to the driver's type of vehicle, vehicle purpose, and income (Agrawal, 2023). A flexible DBC can not only be more equitable but can also strengthen complementary goals like reducing congestion and pollution in communities that are most affected. The more information is available about people's tax burden, the better revenue collection can be tailored to be more equitable, including through subsidies to lower-income drivers (Spiller et al. 2018). However, important hurdles to this approach are data privacy and protection and equitable access. There are no existing examples of linking administrative data (e.g., tax data) to implement travel subsidies that show program effects or comprehensiveness of addressing potential burdens to low-income drivers.

The equity impact of TNC charges can run through multiple channels by affecting drivers, level and cost of service for users, and other road users (Li et al., 2021). Brown (2022) shows that variable fees that take into account time of day, location, and pooling can shift the burden of fees on higher-income locations and create a more progressive fee structure that generates substantial revenues for cities.

Synergy

The uniform application and generally low rate of gas taxes create few opportunities for synergy. In contrast, flexible DBC structures, especially those that include congestion pricing, have a greater potential for synergies. The addition of a congestion module to a DBC program significantly decreases driving as shown in Table 3. Furthermore, congestion pricing through a DBC can have a greater effect on VMT in denser, mixed-use neighborhoods (Guo et al., 2011).

Confidence

Evidence Quality

The studies focused on gas prices are part of a mature field of study that has used rich data and sophisticated methods. There is growing confidence in the newest elasticity estimates as researchers reach similar results using different methods and data. In addition, some of the studies (e.g., Kilian and Zhou, 2022 and Levin et al., 2016) explicitly test why studies may have found divergent estimates based on timing, period of study, type and aggregation of data, and method. These studies show the source of bias and how methodological innovations resolve them.

Research on DBC benefits from being based on pilot programs. The pilots collected rich data that surpasses in quality and depth what is usually available to researchers. The main drawback is the scale of the pilots, which limits researchers' ability to generalize and ask questions where the sample size is too small.

Studies of TNC charging suffer from the dual limitations of studying a very new program and having private companies as the gatekeepers of the data that would allow for a fuller analysis. These limitations have led some researchers to rely on simulations. While the simulation framework expands the possibilities for analysis, they are, in each case, based on the same privately controlled data.

Caveats

Research on the effect of TNC fees relies to a large extent on complex models that simulate a real market and produce estimates for the impact of different kinds of charges. The benefit of these studies is that they evaluate different strategies in a context where few real-world applications exist. The downside is that recommendations will vary with the kind of model researchers developed. For example, Li et al. (2021a and 2021b) recommend using a one-way congestion cordon fee but Zhang and Nie (2021) conclude that a trip-based fee is preferable.

Technical & Background Information

Study Selection and Methodological Considerations

The large literature on the effects of gas prices on gas consumption has evolved significantly in the last 10 years, enough to warrant a re-evaluation of the conventional wisdom that gas consumption is nearly perfectly inelastic. The study of gas consumption has always relied on aggregate data due to the difficulty of measuring gas consumption at the individual level. The studies we selected, rather than using new data, use more sophisticated methods that address some of the limitations of older studies. Key considerations were the ability to model the effect of time, notably drivers' changes in behavior in anticipation of price increases or decreases, and the links between changes in gas demand, gas price, and gas consumption when using aggregate data. The included studies use an instrumental variable approach to disentangle the link between gas demand and gas price (Coglianese et al., 2017; Kilian and Zhou, 2022) or high-frequency data at a lower level of aggregation to address the issue of timing (Levin et al., 2017). While we excluded studies based outside the United States, research on Denmark and Japan find elasticities of gas consumption with respect to gas price on the same order of magnitude as that reported in Table 1. Gilligham and Munk-Nielsen (2019) find an elasticity of -0.3 when adjusting for the higher access to transit in Denmark. Kilian and Tanaka (2021) find an elasticity of -0.37. Both studies benefit from much greater detailed individual-level data than US studies.

Vehicle miles traveled has been measured more systematically at the individual level. All included studies in Table 2 take advantage of repeated measurements for individual vehicles that can be linked to owner demographic characteristics. The studies that included a large share of the car stock (as opposed, for example, to the National Household Travel Study) were prioritized because they allow the researchers to control for demographic, neighborhood, and vehicle characteristics.

Among the limited number of studies focused on distance-based charging and TNC charging, the main distinction is between analyses based on observed data and those based on simulated data. In the case of DBC, we use only studies based on observed data from pilot studies. Studies based on simulated data reflect the specifications the researchers use and may not apply in a real-world situation. Yang et al. (2016), for example, use the Maryland statewide transportation model which comes with a set of assumptions and characteristics particular to this model. As noted in the Caveat section of the brief, we include the TNC charging studies based on simulation 1) because there are very few studies on this topic and only three cities have programs that would allow empirical evaluation, and 2) to show that different programs and specifications can lead to contradictory recommendations.

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