Tax Flights

Koleman Strumpf*
Wake Forest Department of Economics

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Abstract

Tax evasion is difficult to measure, since evaders try to avoid detection and counter-factual behavior is hard to establish. I overcome these issues in the context of a mobile asset, general aviation aircraft. Strategic plane owners typically can evade property taxes by flying to certain locations on a particular date. Using a database of several million individual flights, I measure such "tax flights." To distinguish between tax-motivated flights and typical flight traffic, I exploit variation over time, place and individual in evasion's benefit (taxing and non-taxing states, state and local tax rates, plane value, exemptions for certain planes, tax valuation methods) and cost (distance to non-taxing jurisdictions and fuel costs) as well as other institutions (assessment date). I find evidence that tax flights are higher in taxing states just before the tax date. There is direct evidence of evasion as planes which take tax flights are missing from local tax rolls. Business-owned aircraft are more likely to make tax flights than personal owned ones, as are planes where the owner lives in very high income or wealth areas. While relatively few planes evade taxes, they are disproportionately high value and so there is a large reduction in the tax base. The results have implications for optimal tax theory and policy, particularly with regards to evasion costs and deadweight loss.

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1 Introduction

A central issue in public economics is the extent to which individuals or firms evade taxes. The most recent estimates suggest an annual US tax gap of about $450 billion (IRS, 2016), and leaked documents such as the 2016 Panama Papers and 2013 ICIJ reports suggest upwards of $5 trillion in assets are located in tax havens resulting in $200 billion in lost tax revenues. These are rough estimates because evasion is difficult to quantify: it is hard to observe (evaders hide their actions) or to establish the counter-factual (what behavior would have been like in the absence of taxes). For example, an investor may use hard to monitor off-shore accounts but this may in part be done for diversification purposes.

This paper considers an application, the property taxation of general aviation (GA) aircraft, in which such issues might be overcome. These taxes are levied in some states and are based on the plane's location on a specific date referred to as the assessment date. Strategic plane owners might try to evade the property tax by flying their plane to a non-taxing jurisdiction just before the assessment date and return shortly thereafter.[1] Such *tax flights* could plausibly succeed since planes are mobile and tax authorities rarely have a complete database of all planes in their jurisdiction (in contrast to other property such as homes or autos).

Precisely measuring tax evasion is possible in this environment: the researcher has better information than most tax authorities. The flight activity of specific GA planes can be monitored using data from the Federal Aviation Administration (FAA). The counter-factual of how many flights there would be around the assessment date in the absence of taxes can be established using variation across time-plane-location in tax policy (taxing vs non-taxing states; local tax rates), in exemptions for certain classes of planes (which can vary over time within a state), in costs of evasion (distance from a non-taxing airport; fuel cost), in type of plane, in tax valuation method, and in the assessment date (the latter two vary across states). Netting out the counter-factual behavior from actual flights around the assessment date gives a measure of tax flights.

In this paper I use a database of about twenty million trips covering GA flights in the United States during the period 2004 to 2009. For each flight I know the time, location of the arrival and departure airport, the address of the owner, and the type of

[1] Senator Claire McCaskill appears to have used such a strategy to evade $300,000 in property taxes over four years on a plane she co-owns (Scott Wong and and John Bresnahan, 21 March 2011, "McCaskill to pay back taxes on plane," *Politico*).

plane. I match this to a database of local tax rates and valuation of planes to measure the potential tax bills. For the average plane in a taxing state the (imputed) annual property tax bill is $3400 in year 2009 dollars, but this value is significantly higher for planes which make inter-state flights around the assessment date. The estimates indicate the presence of tax flights. Consistent with a rational model of tax evasion, the propensity to take a quick round trip to another state is significantly higher in taxed states and in times just around the assessment date relative to other planes and times. This propensity is increased when the local tax rate is higher, and is decreased when the cost, as measured by the cost of flying the particular plane model to the nearest airport which allows evasion, is higher. After controlling for typical flight patterns due to temporal, spatial or plane-model specific factors, I find that about five percent of planes engage in tax flights. There is substantial heterogeneity in such activity: tax flight planes are disproportionately high valued models like business jets, and involve locations and times when evasion costs are lower (airports near state borders and years when fuel costs are lower). These flights reduce the potential tax base by about a fifth. Depending on the what factors are considered wasteful costs the deadweight loss is five- to twenty-percent of the revenue actually collected.

The results are robust to various identification strategies such as focusing only on differences across states or within tax states. I provide direct evidence that these tax flights are being used to avoid taxes. I obtain the annual tax roll for a subset of the data, and show that planes on tax flights are almost all not paying taxes while planes which are exempt from taxes tend not engage in tax flights. There is hysteresis in actions, as the same planes continue to evade or to not evade. Finally I look at various covariates of tax flights. Business-owned planes are more likely to engage in tax flights than personal-owned planes, as are those whose owner lives in very high income or high real estate wealth areas. These results can help inform models of tax evasion.

While the application here is unique, it is important to note that timing behavior around a specific date is a common strategy to avoid or evade taxes. For example, the New York City income tax is only owed by residents, defined as someone who lives in the city for any part of at least one hundred and eighty four days in the tax year. Wealthy individuals, who would owe millions of dollars in taxes, are known to rush across the city border just before midnight to avoid reaching the residence threshold.[2]

[2] *New York Times*, "Plan to Tax the Rich Could Aim Higher," 25 October 2013.

Another case is the tangible personal property tax which is based on location and value on a particular date. Since this is a tax on property which can be touched or moved (primarily business equipment and inventory), the same kind of temporary relocation strategies examined here might be used to escape payment. Such evasion has played a role in the reduced reliance on the tangible property tax. Other examples of timing-based tax strategies from the literature include Dickert-Conlin and Chandra (1999) on birth dates, Kopczuk and Slemrod (2003) on death dates, and Grinblatt and Keloharju (2004) on stock trades which may induce the January effect (Thaler, 1987). My estimates are comparable with those found in these papers, though an advantage of my application is that the underlying behavioral response is explicitly specified and observed.[3]

I build on the large literature which empirically measures tax evasion or avoidance (see the summary in Andreoni, et al 1998; Slemrod and Yitzhaki, 2002).[4] Recent papers have relied on range of approaches to calculate the extent of tax evasion including examining clustering due to tax code discontinuities (Best, et al, 2015; Chetty, et al, 2011; Kleven and Waseem, 2013; Kleven, et al , 2011), comparing overlapping administrative records (Fisman and Wei, 2004), changing regulator detection strategies (Casaburi amd Trioano, 2016; Marion and Muehlegger, 2008), comparing expenditures and reported income for different groups (Gorodnichenko, et al, 2009; Pissarides and Weber, 1989), changing public disclosure (Slemrod, et al, 2015), altering perceived audit probabilities (Pomeranz, 2015), developing novel data sets (Merriman, 2010) and inferring third party information (Artavanis, et al, 2016).[5]

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[3]I find that typical tax bills (about fifteen thousand dollars on high value planes) induces a five percent rate of tax flights around the assessment date. Grinblatt and Keloharju find a seven percentage point increase in the tax motivated wash sales of stocks with large capital losses relative to those with gains around the start of the tax years, and Kopczuk and Slemrod show that a policy inducing a ten thousand dollar federal estate tax difference shifts two percent of deaths from the high to low tax regime. Interpreting the literature cases is more challenging than with the application here. For example, the first two papers listed in the text can involve both tax avoidance (re-timing of behavior) and evasion (fraudulently dating birth or death certificates), and these channels would respond differently to changes in the tax or enforcement environment. This paper involves only re-timing evasion.

[4]Tax evasion is formally defined as willful actions which result in the illegal underpayment of taxes. In contrast tax avoidance involves legal tax mitigation strategies. The behavior in this paper is legally murky, but I will refer to it as tax evasion. I do not distinguish between these two behaviors in the remainder of the paper.

[5]Another approach is to estimate aggregate evasion. Zucman (2013) cleverly exploits differences in national accounts to estimate the total amount of developed country wealth held in tax havens. My paper complements this macro analysis by identifying which kinds of individuals and firms

A challenge for these papers is to verify the accuracy of their indirect tax evasion measures, which is difficult because the underlying behavior is unobserved. For example Kleven et al (2011) use audits to measure evasion, but audits still miss much of unreported income and this non-detection rate is heterogeneous across different income categories (Slemrod, 2007). Gorodnichenko, et al (2009) use the difference between reported consumption and reported income as a proxy for tax evasion, which again is likely to induce heterogeneous measurement error. I can more directly establish evasion occurs though two features of my data: it includes almost all flight activity (including the behavior of tax non-compliers) and for a subset of planes tax rolls are available which can be used to verify whether strategic flights are being used to evade taxes. A second advantage flows from the tax environment. The tax applies to both individuals and firms (though sometimes one of them is exempted), so I can compare their evasion rates when they face virtually identical incentives. A wide range of temporal-, location- and asset-specific factors shape the incentives to evade. Empirically I can look at each of these channels in isolation or several at once (for example, relying or just the presence or absence of taxes across states or the actual tax rate within states). This gives more credence to the identification strategies. And the evasion actions are discrete (rather than a more complicated continuous evasion choice, for example how much income to under-report), while the tax rate varies independently from the tax base (with progressive taxes the rate varies with income, so it is hard to disentangle how tax rates rather than income-specific factors shape evasion). Finally the evasion choice is largely driven by observable plane characteristics (the difference between the tax savings and cost of flying) rather than the always hard to measure factors under control of tax administrators (such as the the evasion detection function).

A third advantage is that I have repeat (panel) observations on tax payers. This allows me to establish to the extent of evasion recidivism even after controlling for tax burdens. Explaining the source of such recidivism is important, since the the optimal tax rate should vary depending on how sticky is individual behavior. The panel data also provide additional identification strategies, for example using the removal of the tax in specific year-locations. A final contribution is that I have direct measures of evasion costs (the cost of temporarily moving a plane), which along with other

engage in the activity, measuring dynamic issues such as the rate of recidivism, and helping pin down which environments lead to greater evasion.

components allows me to construct various deadweight loss measures. These costs and their distribution across agents plays a crucial role in setting optimal tax rates for both efficient and equity reasons, though distinguishing between truly wasteful costs and transfers between agents (which do not add to social loss) is subtle (Chetty, 2009). Previous work has not had direct measures of these costs, and so has not been able to partition the evasion response into costly and non-costly components. Similarly, my results on the relative evasion rates of firms and individuals, a topic on which there is little previous work, is also important input to setting optimal tax rates

The paper also adds to the literature on the aviation industry. Most papers here focus on commercial carriers, and address issues such as the impact of hubbing on firm performance (Mayer and Sinai, 2003), the impact of deregulation (Winston and Morrison, 1995), evidence of price discrimination in ticket prices (Borenstein and Rose, 1994), response to potential entry (Goolsbee and Syverson, 2008), rules for optimal airport congestion pricing (Brueckner, 2002), or factors influencing vertical integration (Forbes and Lederman, 2009). This paper has a different focus, looking at issues related to public economics rather than industrial organization. Also I study another segment of the industry, general aviation, which allows me to investigate differences between private and commercial owners which cannot be evaluated using scheduled airline data.

2 Background

2.1 Institutional Framework

This paper focuses on GA aircraft which includes almost all civil aviation besides airlines. It includes both commercial and non-commercial aircraft, aas well as a wide range of plane types including reciprocating (piston) engines, turboprops, light jets, and experimentals. GA can have individual or firm owners, and they span from inexpensive kit models to multi-million dollar jets. There are over 13k GA airports in the US, 350k GA aircraft registered with the FAA (about a third of these planes are inactive and will be omitted from the analysis), and about 2k GA models (this count excludes kit models).

Figure 1 maps state tax policies on GA aircraft (The Data Appendix contains a list of sources used to generate the stylized facts in this section). Eighteen states allow local governments to levy some form of personal property tax on these planes. While most taxing states are in the south or west, there are non-taxing states in all regions (in 2010 forty percent of GA traffic involved taxing states). Among taxing states, twelve tax all aircraft, five tax just business-owned aircraft, and one taxes just personal-owned aircraft. The taxing states assess planes on a single date, which is 1 January in sixteen cases and other dates in two others. In seventeen of the states there is a uniform method of determining assessed values (a fraction of current retail or wholesale price, a depreciation schedule based on purchase price, and other permutations) and one state allows each county to pick their own method. Several states also have a variety of exemptions for particular planes (such as planes older than a certain age or planes used in agriculture). States primarily use a tax situs based on the plane's location though two use the owner's location.

The property tax system is locally administered (Unlike with autos, there is no state registry of all planes. The FAA keeps a registry which it updates semi-monthly). While the state sets the basic rules as described in the last paragraph, counties are in charge of collecting the tax. Most tax officials appear to devote little time or expertise to aircrafts.[6] A reason for this is few counties have specialists in aircraft taxes, and the division which typically administers it is primarily focused on real property such as homes. Still, some counties have requested a list of planes hangared at local airports on the assessment date (California and Nebraska statutes require airports or hangars to report the list of based planes on the assessment date). This appears to be the main form of detection, so a tax flight away from the airport just before the assessment date would be a simple means of evasion. That is, the plane is unlikely to be detected though the flight does not remove the legal obligation to pay taxes. The tax flights might be unsuccessful when local tax authorities engage in more sophisticated strategies, such as consulting online sources listing recent flight activity by plane.[7]

[6] A graphic example of this may be found in Ryan Kath (2011), "Investigation finds dozens of plane owners not paying taxes, costing local governments big bucks." http://www.nbcactionnews.com/dpp/news/local_news/investigations/investigation-finds-dozens-of-plane-owners-not-paying-taxes,-costing-local-governments-big-bucks-may2011swp.

[7] Tax authorities can also consult plane registries. But these list where the owner, but not the plane, are located. This information is not as useful for enforcement in the majority of taxing states which use plane location as the basis for tax situs.

I have not been able to identify other sources which tax authorities could use. Airports must

The mechanics of aircraft property taxes typically parallel those on other property. The tax owed on a particular plane is the product of its assessed value and the overall set of rates. The assessed value is based on the state system of valuation applied to the specific assessment date. The rate is the sum of those from overlapping taxing jurisdictions, which may include the state, county, municipality, school district, and special districts. These rates are typically adjusted each year. A key difference from other forms of property taxation is that no bill is typically sent out, but rather owners are responsible for submitting forms along with payments.

An important question is what happens to a plane owner who is found to have evaded taxes. There do not appear to be clear rules on this but from extensive discussions with local and state tax authorities as well as several aviation attorneys (see Data Appendix) it appears that the owner typically must pay all back taxes plus a multiplicative factor which is proportionate to the unpaid taxes. That is the payment is proportionate to the amount of taxes which have been evaded. This condition will be used in the next sub-section.

2.2 Simple Model of Tax Evasion

Consider an owner who is deciding whether to evade property tax payments on his plane. This is a version of the standard Allingham-Sandmo-Yitzhaki type model in which the choice variable is discrete and where the only a portion of income is taxable. Suppose the plane has assessed value B and faces a property tax rate of t. If the owner does not evade he pays taxes of tB. If he evades, he is caught with probability p and must pay a penalty $\Delta > 1$ on the understated taxes, and if he is not caught then he pays no taxes. It costs c to evade taxes. A risk averse owner with other income I will evade if,

$$\text{Evade} \leftrightarrow (1-p)U(I-c) + pU(I - \Delta tB - c) > U(I - tB) \tag{1}$$

annually report to the FAA National Based Aircraft Inventory Program a list of planes typically hangared there. However the FAA has explicit rules which forbid the sharing of this information with anyone besides state aviation departments. A second possibility is to get records from insurance companies. But insurers generally do not have complete list for any given airport (the industry is relatively fragmented) and some insurers do not even track where the plane is located (it is more important to know the plane is hangared and protected from the elements). Finally the tax authorities could directly request the airport for a list of planes which are typically hangared there. However, the commissions which govern such airports are typically closely aligned with plane owners and are unlikely to honor such requests.

where $U(\cdot)$ is the utility function with $U' > 0$ and $U'' < 0$. The left hand side of the inequality is the expected utility of evading, with the first term representing the case where the owner is not detected and the second term is the case where he is detected. Note that even if evasion is unlikely to be detected, paying the tax is optimal if the costs are high.

Under this framework, the following comparative statics hold. The propensity to evade is decreasing in the probability of detection (p), in the penalty (Δ), and in the cost of evasion (c). The other terms have an ambiguous effect, e.g. both the benefit (avoided tax) and cost (penalty) of evasion are increasing in the plane value. In practice p is quite small in which case the propensity to evade is increasing in the tax rate (t) and the value of the plane (B) and is decreasing in income (I).[8] All of these implications are testable. However I do not have data about the first two points, so in the empirical application I will focus on the relation between evasion and evasion cost, tax rate, plane value and owner income (I will sometimes focus on the tax bill, tB, which should increase evasion rates).

2.3 Identification

The key question is how much flight activity, presumably wasteful, does this tax system induce. The extent of tax evasion can be measured from several sources of variation:

(i) taxing versus non-taxing jurisdictions: one can compare flights in states which allow local governments to levy property taxes with those in non-taxing states;

(ii) tax rates and assessment methods: in states which allow taxes, local governments vary in both the rates they apply and their methods of setting assessed values;

(iii) flight costs: it is less costly to fly to a non-taxing location if the plane is located

[8] The cost of evasion might also be a function of plane value: operating cost per mile (see Section 3) is higher for jets than it is for inexpensive piston engine models. This means that B has an ambiguous effect on the propensity to evade, though in practice for planes which evade the tax bill is far larger so the comparative statics in the text will hold (much of the variation in evasion costs stem from geographic distance as well as fuel costs; I also estimated the relationship between plane value and operating costs and find that costs increase far more slowly, details available upon request). Note that the income comparative static follows due to the assumption of risk aversion, and also holds only for parameters where the decision to evade is optimal.

at an airport near the state border or at times or places where the cost of fuel is low (plane types also differ in their fuel mileage);

(iv) plane types: some planes are more valuable than others, and as such face different potential tax burdens if they do not evade;

(v) special exemptions: some states only allow taxation of certain kinds of planes, such as business-owned, non-business owned, or those less than a certain age;

(vi) a natural experiment (West Virginia effectively made business planes exempt in 2009 while previously all planes were taxed).

Note that there is variation across time, location (both state and sub-state), and plane. These are plausibly exogenous, though I discuss below ways of dealing with endogeneity. For reference Figure 2 overlays tax units in the taxing states (in red) on a map of all airports in the U.S.

The goal is to see the change in behavior of the treated group (plane owners facing a property tax and during the assessment date) relative to a control period (non-taxing period) and relative to control planes (plane owners not facing the property tax). Based on the model in Section 2.2 the main specification to be estimated is,

$$\begin{aligned} Flights_{igt} \;=\;& {}_1 TaxTime_{gt} \times TaxState_g + {}_2 TaxTime_{gt} \times TaxState_g \times TaxBill_{igt} \\ &+ {}_3 TaxState_g \times TaxBill_{igt} + {}_4 TaxTime_{gt} \times TaxBill_{igt} \\ &+ {}_5 TaxTime_{gt} + {}_6 TaxState_g + {}_7 TaxBill_{igt} \\ &+ {}_8 TaxTime_{gt} \times TaxState_g \times Cost_{igt} \\ &+ {}_9 TaxTime_{gt} \times Cost_{igt} + {}_{10} TaxState_g \times Cost_{igt} + {}_{11} Cost_{igt} \\ &+ \quad + X_{igt} \quad + \epsilon_{igt} \end{aligned} \tag{2}$$

where i = plane, g = geographic location (state or local government), t = date, $Flights$ = a measure of tax flight activity, $TaxTime$ = an indicator for assessment time in that state, $TaxState$ = an indicator for a state that taxes planes, $TaxBill$ = plane i value in g times the tax rate in g at time t, $Cost$ = cost of a tax flight (which will be the operating cost of flying the plane to the nearest airport in another state which can accommodate it), X = controls such as income (this will only be available in some specification, and other will include time fixed effects). The key parameters are ${}_1$ and ${}_2$, which measures how flight activity changes in a taxing state around the assessment time and whether this effect changes with the tax bill, and $_{8}$, which measures how greater evasion costs influence flight activity around the assessment time in a tax state. Theory predicts that $_{1}$, $_{2} > 0$ (since the presence of the tax and higher tax bills should increase evasion during the assessment period) and $_{8} < 0$. The other parameters are on control variables, which help capture typical flight behavior not motivated by taxes, e.g. flight volume during the tax period ($_{4}$) or the impact of costs like fuel price ($_{11}$).

Section 4.2 contains results for (2) as well as for simpler specifications which use alternate versions of certain variables (rather than the tax bill, its components tax rate and plane value; for the tax time, the period just before and just after the assessment date) and omits some terms to preserve sample size, to facilitate interpretation or to isolate specific channels of identification. I will consider the effect of income in a specification based on a subset of the sample. That section shows how to use the parameter values to identify tax flights after netting out the usual flight behavior (the counter-factual).

Specification (2) can be thought of as either a regression discontinuity or difference-in-difference design. From either perspective, we can think of comparing planes located near the border of a taxing and non-taxing state, comparing planes which are subject to the tax with those that are exempt, or comparing a taxed plane's flights just before/after the assessment date to further off periods. In the case of the West Virginia law change, we can compare business plane flights in the state after the exemption was introduced to previous years, compare business plane flights to personal plane flights before and after the exemption, and compare these to comparable differences in other states. The key in all these cases is that there is distinct treatment group (non-exempt planes in a taxing state during the tax period) and control group (otherwise). In addition, there are continuous treatment variables, such as the tax rate (which changes over both jurisdictions and over time within a jurisdiction), taxable value of the plane (which varies across plane type, over time within a jurisdiction, and between jurisdictions due to differences in assessment systems), or cost of evasion (which varies across plane types due to different operating costs, time due to fuel cost variation, and locations due to differences in distances from other states).

A final issue is concerns about endogeneity (some of the items here will be added in the next draft). It may be that unobserved factors of flight activity (ϵ in the specification) are correlated with the tax bill. For example, plane value might influence flights. But plane fixed effects largely would account for this possibility. Another possibility is that governments take into account tax flights when they set tax rates (when fixed effects are included, we only have to be concerned about tax rate *changes*). But we have already seen that governments do not closely monitor airplanes so this is unlikely. In addition, this would be hard to implement since as discussed in the next section the same property tax rate is used for other forms of personal and sometimes real property and the overlapping taxing jurisdictions would have to coordinate their rates. Still it is possible to directly account for endogenous tax rates. First, I can eliminate $TaxBill$ terms in the specification so there is no variation in rates (the effect is identified by differences between tax and non-tax states, as well as plausibly exogenous variation in costs due to geographic distance and fuel prices). Second, I can instrument for the tax rates using characteristics of the property tax system (the timing of reassessment or exemptions up to certain property values) which are primarily set based on real property.

3 Data

3.1 Sources

There are several data sets which have to be integrated for the analysis (full details and a complete list of sources is presented in the Data Appendix). The first step is to assemble a database of annual aircraft tax rates. Planes are taxed as tangible personal property, and the rate is typically the general personal rate. An overlapping set of jurisdictions may levy such taxes, including the state, county, municipality (city, borough, township and other sub-county political sub-divisions), and school district (unified, secondary and elementary).[9] While all counties may tax planes, each state has different rules on which of the other government types are permitted to tax.[10] Figure 3 displays the tax units for Texas as an illustration. The tax rate database

[9]In many states single purpose special districts can also levy taxes, but it is not possible to geographically locate all such districts and to match them to addresses as described later in this section. I add the special district rate to a jurisdiction, typically a municipality, whenever they are coterminous. When that is not true, I calculate the average rate for each category of special district (safety, fire, sanitation, water, etc) in each county, and then add the sum of these averages to the county rate.

[10]Among states allowing plane taxes, only Virginia prohibits school districts from levying a property tax.

draws from the Lincoln Institute's *Significant Features of Property Tax* (2010), which lists rates at the county and sometimes sub-county level. A variety of state-specific sources discussed in the Data Appendix is then used to fill in the remaining rates. Figure 4 shows an example of the rates for Texas in 2009.

The second step is to determine the assessed (taxable) values of each plane. This is based on *Aircraft Bluebook Historical Value Reference* (2010) which lists the wholesale and retail price for 1458 plane models and is updated quarterly. Separate values are listed for each manufactured year (that is the price for the 2004 and 2005 version of the same model will differ). The *Bluebook* values are matched to the list of plane models in FAA's *Aircraft Registry* (various years).[11] Through special arrangement with the FAA, I have copies of this file for each month over the period March 2004 to July 2009. The FAA files in aggregate list 71767 unique models. Of these over two thirds are experimental, kit or amateur made and so will not be listed in the *Bluebook*. Many others are redundant listings of the same model (for example the same model will be listed repeatedly if the manufacturer merges or changes its name). In total I can match 2631 of the FAA models to the *Bluebook* based on the manufacturer and model.[12] To determine the taxable value of each plane, I take the base value for each model-manufactured year-quarter adjusted for modifications like a custom engine and use the assessment rule in each state (based on retail value, on wholesale value, on depreciation schedules, or some other system). I impute the tax bill each plane i at time t in location g faces as,

$$TaxBill_{igt} = Value_{it} \times AssessmentFactor_{gt} \times TaxRate_{gt} \tag{3}$$

where $TaxRate_{gt}$ is discussed below. The term is set to zero if the plane is exempted from taxation.

The third step is to associate with each plane the set of taxing jurisdictions, and thus the tax rate and assessed value. Initially various addresses have to be geolocated

[11] All plane owners must register their planes with FAA once every three years. These registrations are the basis for the *Aircraft Registry*. Note that the database includes many inactive planes, since the FAA does not expunge all planes which have not re-registered.

[12] A potential concern is there is sample selection in the match, with lower value models being disproportionately missed. I address this two ways. First, note that while most models are unmatched, the ones which are account for 77% of all flights in the data described below. This is because the matched models are relatively popular (many planes of each model are in use) and are flown relatively frequently. Second, in the estimates I use as an alternate measure the engine type which the FAA reports for most individual planes and is a coarse measure of plane value.

(determine their longitude and latitude). As described in the last section, some states tax planes based on their location and others base it on the owner's location. Plane locations are based on the airport coordinates in the FAA's *Form 5010: Airport Master Record* (2010) and additional sources listed in the Data Appendix. The owners' addresses are listed in the FAA's monthly *Aircraft Registry* (various years). Each file is geocoded using a three step process summarized in Figure 7. In the first step the FAA's *Aircraft Registry* address files, which contain over three hundred thousand records, must be converted from pdf to text format. The next step in the second row shows how coordinates for each address are obtained. The full street addresses are matched to a year-specific database in ESRI ArcGIS (various years), then the zip codes from unmatched addresses are compared to nine-digit zip databases from Maponics (2010) and the USPS (2010). The last step, shown in the remaining rows, is to match the coordinates to taxing jurisdictions. Every location in the United States is located in exactly one state, county, county subdivision, and school district (unified or elementary/secondary); some locations are also located in places (all municipalities are listed as either a county subdivision or place). The ArcGIS software package is used to spatially join each location with the five types of jurisdictions using the boundaries in the Census' *TIGER/Line Shapefile* (various years). Roughly 85% of the addresses can be geolocated in this fashion. This process takes roughly a week of processing time for each set of data, and there are about sixty sets of addresses (corresponding to each monthly FAA registries). Geolocating the airports is completed separately, and this is somewhat simpler since the coordinates are known. Two examples of the output are mapped in Figures 5 and 6 (Figure 2 overlays tax units in the taxing states on the last map).

The final step is to generate a database of plane flights. A log of GA flights in the US for the period January 2004 through July 2009 come from FlightView Inc. These data are generated in the course of normal flight activity when a pilot registers his flight plan with the FAA. The FAA sends a live feed of the flight information to authorized vendors under the Aircraft Situation Display to Industry (ASDI) program. Vendors, such as FlightView, translate the feed into a usable format and remove anomalies (FAA, 2009 provides background on the ASDI program).[13] The final data

[13]There are two sets of flights which are omitted from this feed. First, a plane owner can select to block his plane from either the general FAA feed or from a specific ASDI vendor database (the procedure is discussed in NBAA, 2010). Second, flight logs are only required under instrument flight rules (IFR) while a pilot can instead fly under visual flight rules (VFR) when weather conditions are

include the date, the tail number, the aircraft type, the arrival/departure time and airport, and distance between these airports. There are 210k unique planes and 24m flights.

To this file I add a measure of the cost of evasion. I consider two direct costs, the cost of operating the plane and the value of the pilot's time. For each plane, I calculate the variable cost of flying to the closest airport in a non-taxing jurisdiction,

$$Cost_{igt} = (VariableCostPerHour_{igt} + TimeValue_t) \times Speed_i^{-1} \times DistanceToNontaxAirport_{ig} \tag{4}$$

The two terms in parentheses are the costs per hour: the first is variable operating costs (it is observed annually and is adjusted to reflect monthly-regional variation in aviation fuel cost), and the second is the opportunity cost of the pilot's time (it is based on average hourly earnings and is observed monthly). The other terms generate flying time: speed is the normal cruise speed of the plane model, and the minimum round-trip distance is based on the closest airport in another state which has a runway long enough for the plane model. The cost varies over time t, over space g, and plane i. Note that the temporal variation does not simply reflect macroeconomic conditions, e.g. aviation fuel (one of the key components of variable operating costs) had a temporary spike in 2005. The Data Appendix contains more details on the sources used in this calculation.

Finally some additional data files will be added to help check the validity of the estimates, and to explore the covariates of tax flights. This analysis will be done for a data subset, the Kansas City metropolitan area. The files used will include the annual aircraft tax roll for each county in the metro area as well as various Census files at the Census Block Group level. The Block Groups will be used to proxy for owner characteristics: Block Groups contain roughly one thousand people and are the smallest geographic unit at which the Census files (the 2000 SF3 Long Form and American Community Survey) contains the characteristics of interest.

favorable and the plane does not fly into certain restricted airspaces. A concern is that pilots may strategically utilize one of these options as a method to evade property taxes. There are reasons to doubt these possibilities. First, the blocked list is rather small and is largely composed of planes whose owners are public figures or large corporations (Michael Grabell and Sebastian Jones, 8 April 2010, "Off the Radar: Private Planes Hidden From Public View," *ProPublica*; Mark Maremont and Tom McGinty, 21 May 2011, "For the Highest Fliers, New Scrutiny," *Wall Street Journal*). Second, the proportion of VFR flights actually decreases in the period just before and after an assessment date in taxing states.

3.2 Complications

Some of the tax rate data are not yet available in a form amenable to empirical analysis, and they will be added to the next revision of the paper. Table 1 highlights some of the issues with the local tax rate data. There are several thousand tax units in Texas, Nebraska, Kansas, while there are unusual circumstances in Nebraska, Virginia and Louisiana. California does not have a centralized database of tax rates (according to its Board of Equalization), so county averages will be used.[14]

4 Results

4.1 Motivating Graphs

Before turning to the estimates, it is helpful to visualize the data. Figure 8 shows the weekly number of GA flights for each year between 2004-2009 (only the first half of 2009 is available). A clear seasonal pattern is apparent with a peak during the summer months and a trough in the winter months. This is important for the estimates since the assessment date for sixteen of the eighteen taxing states is 1 January, which is near the trough. There is also a sharp drop in traffic around week 27 which includes the 4 July holiday and is near the assessment date for another state. There is also a drop in traffic in the last three years, likely due to the deep recession at that period. These temporal patterns point out the importance of including both week and year fixed controls in the estimates.

Perhaps the easiest way to see that tax flights might be occurring it to look at changes in imputed tax revenues assuming all planes paid based on their current location. If there were no anomalous tax motivated flights, these revenues would be relatively constant over time (there would be ebbs and flows based on seasonal destinations). Using plane location at the end of each week, I calculate this value for each county: $\sum_i t_i B_i$ where the summation is over all planes i located in the county. and the t tax rate on and B the tax-value of each plane. Note these are hypothetical values, as counties in non-tax states do not collect anything and those

[14] Proposition 13 limits property tax rates in California to one percent, except when a supermajority of voters approve additional levies for school bonds or facilities. In practice this means there is therefore only small differences in tax rates in the state, and so using county averages omits relatively little variation.

in tax states might miss some planes.[15] I then average these weekly values over states which tax general aviation taxes and those which do not (this aggregation removes most of the seasonal patterns since there are both summer and winter destinations in both groups of states). Figure 9 shows the resulting pattern where there are bands around the typical 1 January assessment date, the end of week 52.[16] Tax revenues tend to be stable and follow similar trends in the two sets of states, for example declining in the middle of the year as more planes fly outside the United States. The main exception is in the period around the assessment where there is a large dip in tax collections for tax states and a slightly smaller spike up for non-tax states. This wedge disappears within two weeks after the assessment date. This is consistent with planes flying from tax states to non-states at this time, and then returning shortly thereafter. While this figure is suggestive, it is not complete evidence of tax flights which should be concentrated among high value planes where the evasion benefit is largest. The pattern could be due to many planes, including low value ones, flying. Similarly, it does not explore the geography of tax flights which should be highest in locations adjacent to non-tax states.

The remaining figures provide additional preliminary evidence of tax flights by considering state-level flight patterns. If tax flights occur, then in taxing states there should be a dip in the number of planes located at their "home" airport just before the assessment date and this number should revert right after the assessment date. In non-taxing states, there should be no such dip after accounting for seasonal flight patterns. A second implication of tax flights is that taxing states should have an increase in out-of-state traffic just before the assessment date, and an increase in into-the-state traffic just after the date. Non-taxing states should have the opposite pattern as planes evading taxes fly in and then leave. Comparing the trends away from the assessment period allows us to see whether the non-tax states serve as a suitable control group.

Figure 10 examines home airport patterns. Since it is not completely clear how to determine where a plane is based, I consider three separate definitions of the home

[15] For counties with no plane tax, I use the the county median property tax rate as discussed in the next sub-section.

[16] The figures in this section assumes the assessment date is at the end of week 52, which it is for sixteen of the eighteen taxing states. The other two states are omitted from the taxing group for the purposes of these figures. To ease comparison between the series, I have normalized the non-tax state revenues so it has the same mean as the tax states. The non-tax state revenues are generally about five percent higher, reflecting higher tax rates.

airport: (i) the one where it spends the most time on the ground between flights; (ii) the one where it has the most arrivals plus departures; (iii) the one where it has the most round-trips (flights in which the arrival and destination airport are identical; 2.8% of all trips in the main data involve round-trips).[17] For each of these definitions, I calculate the proportion of active planes which are at their home airport at least once in each week of the year. I then divide the planes by whether their home airport is in a taxing state or not. Figures 10 show the results for the weeks just before and after the typical 1 January assessment date. There is a comparable pattern in all cases. The taxing states see a sharp drop in home airport presence right before the assessment date and then a near reversion to their previous level in the weeks after the assessment. While this is consistent with tax flights, another explanation is that owners are going on an end of the year vacation. The non-tax states provide a control for this. While there is a dip and reversion in home airport presence in non-tax states in this period, it is far smaller and smoother than with the tax-states. Note that aside from the weeks just before or after the assessment date, the two series trend together suggesting that the non-taxing states are a suitable control group.

Figures 11-12 show that inter-state flight patterns are also consistent with tax flights. For both taxing and non-taxing states, the number of out-of-state and in-state flights closely track each other in most weeks, but they deviate in the weeks around the 1 January assessment date. In taxing states in the week before the assessment outbound flights exceed inbounds and the reverse holds just after the assessment period. For non-taxing states the opposite pattern holds, with a higher level of inbound flights before the assessment date and more outbounds afterwards (note that the asymmetry need not hold since the planes flying out of or into tax states could be coming from other tax states). Figure 13 show the same wedge in the neighborhood of the assessment date is evident in each year between 2005 and 2008. Tax flights are consistent with these figures, since it implies planes fly out of taxing states just before the assessment date and return shortly thereafter.

While the graphs here are suggestive of tax flights, because individual planes are not followed it is not conclusive. In particular I have to show that it is the same planes which are making the outbound and then inbound flight (it is possible that

[17]The home airport may be undefined (some planes have no round-trips) or ambiguous (multiple airports can have the same number of summed arrivals and departures). The results discussed below are robust to different approaches to dealing with these cases (e.g. omit planes with no unique home airport or include just one of the airports).

the outbound planes stay out of the state and a separate set of planes fly in to replace them). Moreover, the graphs might understate the extent of tax flights since state-level aggregation eliminates much of the variation in the data: tax rates, cost of evasion, plane valuation, and exemption status. The estimates in the next sub-section address each of these points.

4.2 Tax Flights Estimates

Table 2 shows how the sample of flights is constructed. Starting with the full list of 24.5m flights, about 0.5m are eliminated due to issues with matching to airports. The resulting set of 24m flights will be referred to as the most aggressive sample. Another 3m flights are removed for planes in which aircraft information is unavailable, and the sample of 21m remaining flights is the aggressive sample. Finally, another 0.5m flights are eliminated if there are consistency issues with the flight history, such as an departure time preceding the arrival time of the plane's most recent flight. This sample of 20.5m flights will be referred to as the conservative sample. Table 3 presents summary statistics which detail flight numbers for various subsets, counts of plane type characteristics, and a summary of tax rates. The table also shows that average tax bill for planes which engage in tax flights, defined more formally below, is significantly higher than planes that do not (the overall average is $3400). These bills have a wide range: virtually nothing for experimental or kits, a thousand dollars for piston planes, a few thousand for turboprops, and tens of thousands for jets. The former are particularly helpful since they can be used to evaluate whether flight patterns are similar in taxing and non-taxing states.

Following the simplified model in Section 2.2, the tax flights hypothesis has predictions about the propensity of a plane owner to fly his plane at a particular time. Analysis at the flight level is inappropriate, since inactive planes would be under-represented and highly active planes over-represented. Instead the raw data are transformed to the week-plane level. Week-planes are included if the plane is actively flying or if there is flying activity at both an earlier and later date. This yields an unbalanced panel of roughly 26m flight-weeks (210k planes $\times$ 291 weeks minus weeks before/after the plane enters/leaves the sample). The analysis will focus on various weekly binary flight measures from the home airport using the hours on the ground measure discussed in the last sub-section (the results are comparable using either the flights or round-trip measure).

The first three tables look at the behavior potentially underlying tax flights (in the interest of brevity, costs are omitted from this initial analysis). Table 4 presents logit estimates of the propensity to be at the home airport at the end of the week. Column (1) shows that planes whose home airport is in a taxing state are more likely to be at their home airport, though this effect is rather small (the odds of being at the home airport, relative to a non-taxing state airport, increase by a factor of 1.10). Column (2) adds terms involving an indicator $PreTaxTime$ which in a taxing state takes on a value of one in the week before the assessment date and zero otherwise and is similarly defined for a non-taxing state using the typical 1 January assessment date. The negative term on the interaction $Tax\ State \times PreTaxTime$ shows that planes in a taxing state are absent from their home airport just before the assessment date relative to other periods and to non-taxing states (the odds ratio is 0.74). Tax flights might be the mechanism here, as owners fly away from their home airport just before their planes are assessed. Note that consistent with the graphs in the last sub-section there is an important seasonal effect, the negative parameter on $PreTaxTime$, showing the importance of including non-taxing states as a control. This specification (and similar ones in the tables below) is of interest since it is based only on cross-state differences, and so identification will not be threatened if local tax rates are endogenous. Column (3) shows the tax flight effect increases with the tax rate.[18] The $Tax\,State \times PreTaxTime \times Tax\,Rate$ parameter shows that the odds of being at the home airport is multiplied by 0.73 for a one unit increase in the tax rate. The other terms involving the tax rate are small and not statistically significant, indicating tax rates do not shape the propensity to be at the home airport in other time periods or in non-taxing states. Column (4) shows the results are robust to the inclusion of week fixed effects. Column (5) uses $TaxBill$, defined in (3) and in thousands of 2009 \$, instead of tax rates as the more appropriate measure of the potential benefit of evasion (it is larger for more valuable planes, set to zero for exempt planes, and varies across time, plane and geography). The estimates are comparable in sign and scale as the earlier columns, though the results are less precise and the the sample size is smaller due to missing values for the underlying plane value variable (see Section 3).

[18]Due to issues with local tax rates discussed in Section 3.2, I use county median property taxes as a percent of assessed values over 2005-2009, described in the Data Appendix. The mean is 0.89 and standard deviation is 0.49 across all counties. This variable is also used to calculate $TaxBill$ in (3) for taxing states.

Tables 5 and 6 present estimates of the propensity of planes owners to engage in inter-state flight out-of or back-to their home airport. These estimates involve a restricted sample since the plane must be located at the home airport at the start of the week in the first case or in another state in the second case. The parameters in these tables are also consistent with tax flights. Column (1) shows that inter-state flights patterns are roughly comparable between taxing and non-taxing states. Column (2) shows that plane owners with a taxing home airport tend to fly out of their home airport to another state just before the assessment date ($Tax\ State \times PreTaxTime$ in Table 5 has odds ratio of 1.42) and back to their home airport from another state just after the assessment date ($Tax\ State \times PostTaxTime$ in Table 6 has odds ratio of 1.34, where $PostTaxTime$ which is defined analogously as $PreTaxTime$ except it is for the week following an assessment date). Column (3) shows that higher tax rates accentuate these effects, and column (4) shows that that the effects are robust to controls for week fixed effects. The last column shows that the estimates are qualitatively similar if the more appropriate $TaxBill$ variable is used instead of tax rates.

Table 7 is the most direct measure of tax flights and follows the specification in (2). Among planes which are located at their home airport in the beginning of the week, it considers whether the owner flies to another state in the current week and then returns in the following week. The dependent variable is an indicator for such round-trip flights, and the sample is again only planes located at their home airport at the start of the week. The parameter on the $Tax\,State \times PreTaxTime$ interaction in column (1) shows such round-trips are significantly more likely to occur in a taxing state just before the assessment date, relative to other times and to non-taxing states. Note this specification only uses cross-state differences, and so there is no concern about endogenous tax rates. The remaining columns add terms representing the cost and benefit of the tax flights. Column (2) uses tax rates and a proxy for plane value, engine type, to measure the benefit and aviation fuel price to measure costs (These somewhat imprecise measures are used since the preferred variables discussed below result in potentially non-random dropping of observations, see Section 3). These terms are interacted with $Tax\ State \times PreTaxTime$. The tax rate interaction is positive indicating there are more of these round trips right around in the assessment period in localities with high taxes. There are three categories of engine type: in order of increasing value, the categories are $Reciprocating/Piston$ plus $2/4 - cycle$

(the omitted category), $Turbo\,Prop$, and $Turbo\,Fan$. Interstate round-trips from the home airport around the assessment date are far more likely for more valuable planes, with the odds of a turbo fan plane taking such flight being about three times to that of piston or n-cycle planes. The next row shows that the flights are also responsive to direct financial cost, namely the cost of fuel in tax states just before the assessment date. Column (3) shows these effects are robust to controlling for week fixed effects.

Table 7 column (4) is most directly linked to the evasion model, (1). After taking linear approximation to utility and presuming the evasion is rarely detected ($p \to 0$), the net benefit of evasion is $tB - c$. I include direct measures of these terms, *TaxBill* and *Cost*. The sample size is notably smaller here since the two underlying variables (plane value and plane operating costs) are unavailable for all aircraft. The estimates are consistent with the earlier columns: a one thousand dollar increase in the tax bill increases the odds of these flights during the assessment period by twenty five percent and a thousand dollar increase in the minimum cost of such flights reduces the odds by a comparable amount.

Table 8 helps validate the results, presents a robustness check, and provides some extensions. In all cases the basic specification is comparable to the final column of Table 7. Column (1) considers a placebo estimate. Recall that some states exempt from property taxes personal- or business-owned planes while others exempt certain planes such as older models. The estimates indicate that these exempt planes in taxing states are not responsive to tax bills or flight costs around the assessment date. This is evidence that there is not some special factor in taxing states which is driving the these flights. A related placebo test is to use at tax rates in *non*-tax states, and these result in insignificant parameter estimates (this result is omitted) Column (2) focuses on a quasi-experiment. West Virginia taxed all planes through 2008, and then in 2009 effectively exempted business-owned planes. A difference-in-difference interaction is included, and the parameter indicates that the new law substantially reduced the propensity of business planes to engage in these flights relative to their previous patterns (and also relative to personal planes in the state and to planes in other states). This is consistent with tax evasion, since the law change eliminated the need for business planes to fly away to avoid paying taxes.

Column (3) of Table 8 is a robustness check. One concern is that states which permit property taxation and those which do not are somehow different, so the latter is an inappropriate control group. To account for this I limit the sample to just taxing states, where the variation in tax rates is due only to local rates differences (there remains variation in plane value and costs). The estimates on the $TaxBill$ and $Cost$ interactions are comparable to those from the full sample in the previous table though the parameters are no longer statistically significant. In a related test, I consider a few taxing states in isolation to see if the key parameters are heterogeneous. While there are a few cases like California where the cost and tax parameters are smaller in size, the reduction in sample size and increases in standard errors make it difficult to draw firm conclusions (this result is omitted). Similarly I omit airports in vacation destinations– Florida, Arizona, Colorado– and the key parameters do not significantly change (this result is omitted). The remaining columns look at two extensions, both of which are explored in more detail in the next sub-section. Column (4) shows that the odds of a business-owned plane taking a these flights are about three times those of other planes. This suggests business planes are engaging in more tax evasion. The last column shows that a plane which took a round trip interstate flight last year around the assessment date has odds which are seven times greater than one which did not. This suggests that behavior is persistent, and that the same set of planes take/do not take these kinds of flights.

Returning to the main estimates I now formally measure tax flights. The goal is to look at short flights from a home airport to another state with a quick return, but to control for typical flight patterns for example due to seasonal variation or plane model-specific patterns. To do this I use the last specification in Table 7 to fit the probability of such a flight for each plane using the observed covariates, tax bills and costs, and then difference out using the same covariates but forcing tax bills and costs interactions with $TaxTime \times TaxState$ to be zero,

$$\begin{cases} Pr(Fly|TaxBill^{3way}, Cost^{3way}, X, \hat{\ }) - Pr(Fly|0, 0, X, \hat{\ }) & \text{if tax state, tax time, non-exempt} \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

where the superscript indicates the three-way interactions, and I omit subscripts in the interest of brevity. In the top row, the first term represents the predicted tax flight-type behavior and the second term is the control for the usual rate at which flights occur for non-tax reasons (the counter-factual). Note that the non-interacted $TaxBill$ and $Cost$ terms remain in the counter-factual, so for example the background level of tax flight-type activity will be lower in locations requiring longer flights and so requiring higher costs (the difference will also be smaller, since costs also enter via the interaction as well directly in the first term).

A tax flight occurs when this difference exceeds 0.5. Note this can only occur for specific plane-location-times (for planes which owe the tax in taxing states during the assessment period), and is a relatively high cut-point given that the counter-factual probability is netted out. By this measure about five percent of all planes engage in tax flights (the rate among eligible planes is much higher, since about half of the planes have a home airport in non-tax state and many others are exempted due to age or ownership rules). There is also substantial heterogeneity. Due to the large positive effect of the tax bill, tax flights are much more common in high value planes (about a fifth of jets) and virtually never happens with low valuation planes (like experimental or kit planes). And because the costs of evasion are largely proportionate to distance for non-taxing airports as in (4), tax flights are several times more likely in locations straddling state borders compared to the center of large states. It is significantly lower in periods of high fuel costs.

Finally Table 9 summarizes these results with an efficiency analysis, a calculation of the revenue and social loss of the tax. Various approaches to calculating each of these terms is presented. In all cases I calculate values at the county-level. In the top of the table I calculate revenues at each airport, first by looking at all planes located there on the assessment date and second by assuming planes are taxed at their home airport but only if they are present during the assessment date. In both cases I assume that planes which are absent on the assessment date do not pay tax. The average value of the two revenue totals are comparable, and when I apply them to a subset of counties for which I have the actual tax roll (discussed in the next section) the observed values are within ten percent of one of these. If instead I assume all planes are taxed at their home airport regardless of their location of the assessment date, revenues increase substantially. This should be viewed as the potential tax base, and the observed tax collections I discuss in the next section are lower by a similar margin. In the bottom of the panel I calculate deadweight loss associated with tax flights, as identified above. However, as Chetty (2009) points out, it is important to distinguish between evasion activity which is truly wasteful (productivity reducing) and those which are simply transfers between agents. I consider two components of cost which might be wasteful, the cost of flying and the opportunity cost of the pilot's time (congestion costs are likely to be minimal due to the low levels of flight activity around the typical assessment date). In each case I consider cases which satisfy the tax flight definition and calculate costs following (4). Depending on the what factors are considered wasteful costs the deadweight loss is five- to twenty-percent of the revenue actually collected. Aggregated to the national level, the property tax leads to about $400m in taxes collected per year, an additional $75m could be collected if there were no tax flights, and there are about $50m in deadweight loss.

Two additional channels of deadweight loss will be discussed in the talk:

- CO2 emissions / carbon footprint
- Flight accidents

4.3 Validation of Estimates

In the remainder of the paper, I will focus on planes with a home airport in the Kansas City metropolitan area. This region includes fifty-nine GA airports located in seven Missouri and Kansas counties. This is an interesting area to look at because the costs of evasion are low as a state border bisects it, both states tax planes but only Kansas exempts business-owned planes, and there is a strong aviation culture so strategies to evade taxes might be commonly known and shared. In short, this is a perfect storm for having tax flights.

In this sub-section the goal is to provide direct evidence that tax flights are being used to avoid paying taxes. I obtained the annual aircraft tax roll for each county over 2004-2009 (see the Data Appendix). These rolls include the owner name, address, plane and tax amounts for any plane on which property tax has been paid. For each of these counties, I assemble the list of planes which have a home airport located in the county. I then see how many of these planes are predicted to take a tax flight as defined in (5). I check how many of these planes actually take round-trip interstate flights from their home airport around the assessment date. A test for the evasion theory is whether the set of planes predicted to take tax flights overlaps significantly with those missing from the tax roll, and also that those which actually make such flights but are not predicted to do so (reflecting typical seasonal flying) are on the tax roll.

The first step is to compare predicted with actual flying behavior. Most planes satisfying the tax flight condition in (5) should in fact make round-trip flights around the tax date. This is what I find: over 90% of the planes satisfying (5) complete a round-trip flight out of and the back to their home airport around the assessment date (some planes not satisfying this condition also engage in similar flights, reflecting the typical flight activity and the small costs of such trips).[19] The next step is to see whether planes defined as taking tax flights are missing from the tax rolls.

Table 10 summarizes the data. Three points are worth stressing. Panel (a) shows that about half of the planes with home airports in Missouri and a third of the planes in Kansas do not appear on the tax rolls (there are few planes in Kansas because of the large number of exempt planes which will be discussed below). This a far higher rate of evasion than seen in other contexts like income taxes. The final two sets of columns show that tax flights seem to be used to evade taxes. There are about as many tax flights as planes missing from the tax roll, and almost all planes satisfying the tax flights condition are missing from the tax roll. That is, the set of planes engaged in tax flights and the set not on the tax rolls are virtually the same.[20]

The remaining two panels of Table 10 are also consistent with tax flights. Panel (b) considers exempt planes which can serve as an implicit control. In Missouri most business-owned planes are taxed. Table 10 indicates these planes are largely missing from the tax roll and the missing list includes many planes meeting the tax flights condition. Comparing to the first panel, business-owned planes are far more likely to be missing from the tax roll and a higher proportion of the planes engage in tax flights. In Kansas business-owned planes are exempted but they must still list their plane with the county assessor. Johnson County, which has about two thirds of all Kansas planes in the metro area, lists such exempted planes on their tax roll. Virtually all business planes are listed (I have even found three firm-owned planes which do not pay tax to their appropriate Missouri home county but are listed in the Johnson County tax roll; all satisfy the tax flights condition and one lists their law firm's Kansas address!). This is consistent with tax flights.[21]

[19]Recall costs enter directly in the counter-factual in (5), and directly and interacted with the tax terms in the first term in (5). Costs are low here since airports are near state borders, so the counter-factual tax-flight type behavior is relatively high. This means the first term in (5), the forecasted rate of such flights, will be close to one for planes satisfying the tax flights condition, hence the high rate of actual such trips which are observed in the data.

[20]A supplemental test is whether planes engaged in interstate flights, but do not satisfy the tax flights condition, are on the tax roll. Over 90% of these planes are in fact on the tax roll. As I will show shortly, these are mainly inexpensive planes which face low tax bills.

[21]While Kansas business-owned planes are exempted, I examined cases of observed interstate round trips around the assessment date. The table shows planes which engage in these "tax flights" are almost all on the tax roll, consistent with the maintained assumption that these reflect typical

Panel (c) of Table 10 takes advantage of the panel nature of the data. It is possible to track whether specific planes are consistently on or off the tax rolls. Among planes on the tax roll, over two thirds are present for at least five of the six years (Some of those with fewer years are planes which enter in mid-sample either due to a plane re-location or a new purchase). The same pattern hold in both states and for business- and non-business owned planes. These owners rarely make tax flights. As a corollary the missing planes remain off the tax rolls in almost all years. A potential explanation is that the decision to pay taxes is irreversible, since after paying once the tax authority is aware of the plane and it will be more difficult to claim the plane does not exist.

A final point is that it is disproportionately high value planes which are not paying taxes. Figure 14 shows the distribution of annual taxes for the tax roll and those which are missing. Planes on the tax roll are far less valuable and face relatively lower tax bills (a median of $865 in 2009 dollars and a mean of $2113). Alternatively, planes missing from the tax roll face significantly higher bills (median of $1610 and mean of $7214), largely due to the shift in mass from the the under five hundred dollars bins to the five thousand and greater bins. A Kolmogorov-Smirnov test rejects the null that the distributions are identical ($p = 0$). This pattern of higher tax bills inducing greater evasion is what the theory predicts.

All the points here are consistent with tax flights being used to evade taxes. Planes engaged in these flights tend to be missing from the tax roll, but there are few similar-type flights for planes which are exempt from the tax. As with the national sample, non-exempt business-owned planes have higher rates of tax flights and as we see here actual tax evasion. Planes missing from the tax roll (which are mainly ones engaged in tax flights) also tend to face higher property tax bills as theory suggests.

4.4 Covariates of Tax Evasion

It is possible to roughly see what demographic characteristics are associated with tax flights. This is possible since both the flight data and the tax roll include the name and address of each plane owner. While I do not observe the actual demographics of the owners, I can proxy for them using the characteristics at the Census Block Group level. The goal is to see what characteristics are associated with tax evasion. In

background flight activity (see also note 20).

the analysis below, I use only individual-owned planes (earlier sections showed that business planes tended to evade more and to take more tax flights).[22]

Table 11 shows the results for the Kansas City metropolitan sample discussed in Section 4.3. For each year-plane in the sample, I generate an indicator if the plane satsifies the tax flight condition and another indicator if it is also missing from the tax rolls. I then run a series of logits comparing these dependent variables to demographics variables derived from Census sources (see the Data Appendix).

The first set of results look at various household income measures. Median income has only a modest effect (and is not statistically significant). Alternatively having a household income in excess of $200,000 leads to more tax flights or greater evasion: a one standard deviation increase (about ten percent higher share of such high income households) increases the odds of these by three to five times. This is in opposition to the theory which predicted higher income would be associated with lower evasion. There are a few possible explanations. One is due to preferences. Higher income could have a greater preference for evading, or in opposition to the model might be risk loving or more risk tolerant than lower income individuals. A second explanation is that higher income allows and individual to purchase a more valuable plane which increases the benefit of evasion (in terms of the model, this means $B(I)$ with $B' > 0$).

The two other income variables in Table 11 look at non-wage income. Increases in self-employment income has an effect which is not statistically or economically significant, while higher non-wage income (interest, dividends or net rental income) has a positive effect on tax flights or evasion: a one standard deviation increase of twenty percent increases the odds by fifty percent. The self-employment income result is of particular interest since recent work has found that there is greater evasion for such income; this is attributed to lower detection probabilities due to less documentation (Kleven et al, 2011). Another possibility is that higher self-employment income may be due to preference differences, for example from individuals such as entrepreneurs with a greater tolerance for risk. The null result here is evidence against this alternative and so adds to the results in Kleven et al (2011) supporting the documentation

[22] By design the sample also omits two groups who are in the KC metro area. First, it does not include resident owners whose planes are primarily based outside the metro area. This is not a big issue since in most cases situs is determined by the plane location. Second, the sample omits planes which have a home airport in the metro area but whose owner lives elsewhere (this is about a fifth of the planes from the full metro subsample). These planes are liable for property taxes, but are not included here since the underlying Census data has only been assembled for the metro area.

channel.

The bottom of Table 11 shows results for various measures of home value which are a proxy for wealth. Mirroring the results for income, changes in the median or in moderately valuable home values has an effect which is not economically or statistically significant. However, a greater share of million dollar plus homes does lead to more tax flights and evasion: a one standard deviation increase of three percent increases the odds by ninety and fifty percent respectively. The same interpretations challenges from the income section carry over here.

In conclusion it is important to make two caveats to the estimates here. First, using Census Block Groups to proxy for owner characteristics may be particularly noisy when looking at low frequency categories like the ones listed above. This lowers the precision of the estimates. Second, the interpretation of the parameters is a bit fuzzy. As pointed out above the estimates could reflect preference, financial or other differences, and these different sources have different implications for both theory and policy.

5 Conclusion

The evidence in this paper suggests that tax flights are a real and economically meaningful phenomenon. While these flights are relatively uncommon, because they occur primarily among high-valued plane models they significantly depress tax collections. I also provide one of the first measures of the cost of tax evasion, and find that there is significant social loss associated with this activity.

These estimates suggest two puzzles: why are these taxes used at all, and if they are why are they not more stringently enforced? My conjecture is that the tax has some appeal in that it gives the appearance of being a progressive tax on an asset associated with the rich, though ironically it is the very valuable planes which are the ones which end up escaping the tax. This is analogous to the progressive intentions behind the 1990-1993 federal luxury boat tax, which raised little revenue due to the apparently unanticipated highly elastic response of affluent boat owners. The limited enforcement could reflect political capture. General aviation airports have received billions of dollars in federal aid (mainly from fees on commercial airline tickets) which pays for almost all capital costs and allows most to charge no landing fees, and yet they are used at far less than capacity. The industry has also been effective at gaining special interest legislation such as the General Aviation Revitalization Act of 1994, which sharply limited legal liabilities for manufacturers with the explicit goal of avoiding the collapse of US GA plane manufacturing. Greater enforcement of the property tax could be self-funding as the results here indicate a relatively simple examination of flight records would generate a typical county about fifty thousand dollars in tax revenues. Still it is worth noting that if enforcement were to increase then plane owners would also respond in new ways to reduce their tax burden. They might buy less expensive planes, forgo buying a plane completely, or use other tax avoidance strategies discussed below. Dealing with such changes on the extensive margin is a fundamental challenge to reforms which seeks to reduce tax evasion in other environments.

In the next revision of this work I will make the following additions:

- **weather (additional variation in flight patterns):** bad weather such as icy precipitation can force pilots to scrap planned trips, an important possibility around the most common assessment date of 1 January. While these conditions can typically be avoided using weather forecasts, sometimes fronts arrive more quickly or slowly than anticipated. I am in the process of assembling a database of actual weather as well as forecasts (three and seven days ahead) from NOAA at the airport-level.

- **dynamic models**: there is evidence that the choice to engage in tax flights is persistent. This suggests dynamic concerns might be important. Still it is not clear how this will influence the evasion calculus, since there are no obvious stock variables in the benefit and cost term (one possibility is the penalty if caught, which may only be based on one year of taxes rather than a full stream of back taxes).

- **alternative estimation approach**: having so many interactions in a non-linear model makes interpretation difficult. Moreover it is challenging to control for plane-specific fixed effects, since the usual route (conditional logits) would drop from the sample any plane which never (or always) engages in tax flights, to instrument for potentually endogenous variables like tax rates, and also to compute conventional marginal effects. It would be easier to use linear probability models rather than logits for all specifications.

- **peer effects**: Given the fine grained spatial data, a natural question is whether the behavior of neighbors influence individual choices. This is important for policy since if they do it suggest social norms matter for tax evasion. The usual reflection problem complicates the estimation of this effect however. One possible solution is to look at how owners who base their planes far from home are both impacted by the non-local tax rates and neighbors. Other approaches could include regression discontinuity (owners on county borders) or comparing planes based at different airports in the same county.

These revisions should provide a more precise measure of tax flights. Still there are other strategies which might be used to evade property taxes on airplanes. Owners might strategically hangar their planes in a non-taxing state, an attractive option for those who live near state borders (for example, owners in St. Louis may base planes in Illinois). Another possibility is that owners could put their airplane on the blocked list, which would prevent third parties including tax officials from monitoring their flight patterns. While this list has been private, the FAA for a short time made this list public (and at least subsets have been released under Freedom of Information Act requests). If either of these distortions of behavior are common, the deadweight loss is even higher than the estimates I find. Exploring these and other tax evasion strategies are interesting topics for future work.

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Table 1: Difficulties with Tax Rate Data

State	Number Taxing Units*	Issues
Texas	2798	
Nebraska	2420-3033	number/names vary over time (government consolidation)
Kansas	2566	
Virginia	505	assessment system varies by county
Louisiana	532	rate variation within school district
California	tens of thousands	No central database of TRA (tax rate area) rates

*Number taxing units excludes special districts (which cannot be geocode)

Table 2: Constructing Flight Sample

Description	Sample Size (Number of flights)
Initial Sample	**24,581,002**
LESS: Airports listed as "?" or "ZZZZ"	(367,188)
LESS: Unmatched airport codes	(285,970)
"Most Aggressive" sample	**23,927,844**
LESS: Unmatched aircraft info	(3,017,764)*
"Aggressive" sample	**20,923,897**
LESS: Problem Data (bad time, bad distance)	(664,298)**
"Conservative" sample	**20,481,368**

*13,817 overlap with omitted observations above
**221,769 overlap with omitted observations above

Table 3: Summary Statistics

Variable	Sample Size
#Flights	**23,927,844**
Week 52	314,223
Week 1	385,007
Tax States	13,753,743
Non-Tax States	16,521,756
#Planes	**212,968**
Aircraft Type (N=48,368 missing)	**164,600**
Fixed wing single engine	112,767
Fixed wing multi engine	45,358
Other	6,475
Engine Type (N=48,368 missing)	**164,600**
Reciprocating	122,990
Turbo-prop	11,931
Turbo-fan	14,677
Other	15,002
Ownership Type (N=48,780 missing)	**164,188**
Individual	53,960
Partnership/Co-Owned	26,030
Corporation	80,445
Other	3,753
	Values
County Median Property Tax Per $100 Value (N=5,153 missing)	
Mean	$0.982
Std. Dev.	$0.394
Min	$0.079
Max	$2.931
Tax Flight Factors (Taxing states only; year 2009 thousands $)	
Mean Tax Bill (Tax Flight)	$12.326
Mean Tax Bill (No Tax Flight)	$2.997

This is for the most aggressive sample. The top panel is at the flight-level includes the number of flights for certain periods near the main assessment date (week 52 = last week of year and week 1 = first week of the year) and for certain groups of states (the sum of flights exceeds the total number of flights since flights can arrive and depart from different states). The remaining panels lists aircraft characteristics, county taxes, and tax evasion factors all at the plane-level.

Table 4: **Estimates: At Home Airport (logit)**

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Constant	0.697	0.711	0.621		
	(0.02)	(0.03)	(0.03)		
Tax State	0.091	0.114	0.141	0.109	0.081
	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)
PreTaxTime		-0.157	-0.121		
		(0.03)	(0.05)		
Tax State×PreTaxTime		-0.304	-0.150	-0.211	-0.157
		(0.07)	(0.05)	(0.04)	(0.06)
Tax Rate			0.017		
			(0.03)		
Tax State×Tax Rate			-0.045		
			(0.05)		
PreTaxTime×Tax Rate			-0.049		
			(0.03)		
TaxState×PreTaxTime×TaxRate			-0.315		
			(0.07)		
TaxBill					-0.051
					(0.05)
Tax State×PreTaxTime×TaxBill					-0.259
					(0.12)
TaxTime/State/Bill interactions	N	N	N	N	Y
Week FE	N	N	N	Y	Y
N	25,834,851	25,834,851	25,834,851	25,834,851	18,433,328
logL	-18123960	-16864685	-15456564	-11456987	-8166469

This is for the most aggressive sample (except (5) which is for the aggressive sample) and is at the plane-week level. The dependent variable is an indicator for whether the plane is at the home airport at the end of the week. Robust standard errors are in parentheses.

Table 5: Estimates: Interstate Flights Out of Home Airport (logit)

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Constant	0.214	0.205	0.257		
	(0.07)	(0.06)	(0.05)		
Tax State	0.071	0.055	0.049	0.030	0.017
	(0.06)	(0.07)	(0.07)	(0.08)	(0.10)
PreTaxTime		-0.211	-0.245		
		(0.09)	(0.11)		
Tax State×PreTaxTime		0.351	0.239	0.273	0.215
		(0.11)	(0.13)	(0.14)	(0.18)
Tax Rate			-0.081		
			(0.05)		
Tax State×Tax Rate			0.056		
			(0.12)		
PreTaxTime×Tax Rate			-0.114		
			(0.09)		
TaxState×PreTaxTime×TaxRate			0.279		
			(0.14)		
TaxBill					0.122
					(0.07)
Tax State×PreTaxTime×TaxBill					0.346
					(0.17)
TaxTime/State/Bill interactions	N	N	N	N	Y
Week FE	N	N	N	Y	Y
N	15,486,123	15,486,123	15,486,123	15,486,123	11,645,646
logL	-9456998	-8546546	-8324566	-6974987	-4327630

This is for the most aggressive sample (except (5) which is for the aggressive sample) and is at the plane-week level. The dependent variable is an indicator for whether the plane flies away from the home airport to another state (planes which are not at their home airport at the start of the week are omitted from the sample). Robust standard errors are in parentheses.

Table 6: **Estimates: Interstate Flights Into Home Airport (logit)**

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Constant	-0.446	-0.375	-0.511		
	(0.07)	(0.04)	(0.02)		
Tax State	0.138	0.119	0.099	0.159	0.066
	(0.07)	(0.06)	(0.07)	(0.08)	(0.10)
PostTaxTime		0.191	0.254		
		(0.09)	(0.10)		
Tax State×PostTaxTime		0.292	0.151	0.229	0.175
		(0.07)	(0.06)	(0.11)	(0.16)
Tax Rate			-0.006		
			(0.02)		
Tax State×Tax Rate			-0.112		
			(0.08)		
PostTaxTime×Tax Rate			0.055		
			(0.03)		
Tax State×PostTaxTime×Tax Rate			0.255		
			(0.10)		
TaxBill					0.148
					(0.09)
Tax State×PostTaxTime×TaxBill					0.217
					(0.13)
TaxTime/State/Bill interactions	N	N	N	N	Y
Week FE	N	N	N	Y	Y
N	7,455,446	7,455,446	7,455,446	7,455,446	5,820,964
logL	-5945635	-5512312	-5148684	-4748646	-3587977

This is for the most aggressive sample (except (5) which is for the aggressive sample) and is at the plane-week level. The dependent variable is an indicator for whether the plane flies into the home airport from another state (planes which are not in another state at the start of the week are omitted from the sample). Robust standard errors are in parentheses.

Table 7: Estimates: Interstate Round-trip Flights Out/Into Home Airport (logit)

Variable	(1)	(2)	(3)	(4)
Constant	-2.512	-2.146		
	(0.17)	(0.156)		
Tax State	0.116	0.099	0.072	0.051
	(0.09)	(0.07)	(0.05)	(0.05)
PreTaxTime	0.279	0.318		
	(0.15)	(0.11)		
Tax State×PreTaxTime	0.856			
	(0.12)			
Tax State×PreTaxTime×Tax Rate		0.277	0.318	
		(0.09)	(0.17)	
TaxBill				-0.015
				(0.09)
Tax State×PreTaxTime×TaxBill				0.225
				(0.14)
Tax State×PreTaxTime×T-Prop Engine		0.612	0.359	
		(0.14)	(0.16)	
Tax State×PreTaxTime×T-Fan Engine		1.090	1.179	
		(0.29)	(0.39)	
Tax State×PreTaxTime×Fuel Cost		-0.619	-0.705	
		(0.15)	(0.19)	
Cost				-0.214
				(0.15)
Tax State×PreTaxTime×Cost				-0.278
				(0.12)
TaxTime/State/Rate interactions	N	Y	Y	N
TaxTime/State/Bill interactions	N	N	N	Y
Engine type Interactions	N	Y	Y	N
Engine type FE	N	Y	Y	N
Fuel Cost Interactions	N	Y	Y	N
Fuel Cost	N	Y	Y	N
Cost Interactions	N	N	N	Y
Week FE	N	N	Y	Y
N	15,486,123	13,545,464	13,545,464	11,645,646
logL	-11915256	-8954656	-8012323	-6605005

This is at the plane-week level. The dependent variable is an indicator for whether the plane flies away from the home airport to another state and then returns the following week (planes which are not at their home airport at the start of the week are omitted from the sample). (1) uses the most aggressive sample. (2)-(4) use the aggressive sample (the sample size is reduced because they omit planes which cannot be matched to a model, and thus some measure of their tax value, or to costs). Robust standard errors are in parentheses.

Table 8: **Estimates: Validation, Robustness, Extensions (logit)**

Variable	(1) Placebo: Exempt	(2) West Virginia experiment	(3) Tax states only	(4) Business-Owned	(5) Hysteresis
Exempt					
Tax State×PreTaxTime	0.056				
×Tax Bill	(0.12)				
Tax State×PreTaxTime	0.004				
×Cost	(0.05)				
West Virginia					
Post-2008×PreTax		-1.345			
Time×Business plane		(0.69)			
Tax State×PreTaxTime			0.325		
×Tax Bill			(0.19)		
Tax State×PreTaxTime			-0.178		
×Cost			(0.15)		
Tax State×PreTaxTime				1.026	
×Business plane				(0.35)	
Tax State×PreTaxTime					2.015
×Roundtrip flight last year					(0.37)
Other TaxTime/State/Bill variables	Y	Y	Y	Y	N
Other Cost variables	Y	Y	Y	Y	N
Other West Virginia variables	N	Y	N	N	N
Week FE	Y	Y	Y	Y	Y
N	11,645,646	11,645,646	5,465,964	11,645,646	15,486,123
logL	-6600146	-6451322	-3437895	-5912347	-12326978

This is for the aggressive sample and is at the plane-week level. The dependent variable is an indicator for whether the plane flies away from the home airport to another state and then returns the following week (planes which are not at their home airport at the start of the week are omitted from the sample). The base specifications are comparable to (4) from Table 7. In specifications (1) and (2), the listed variables are interacted with the header variable in bold text. The "Other" variables include all possible level and interaction terms. Robust standard errors are in parentheses.

Table 9: Revenue vs Deadweight Loss Calculation (thousands 2009 $)

Variable	County Average
Revenue (on assessment date)	
Planes currently at airport	275.68
	(168.67)
Planes present at home airport	224.56
	(94.56)
Planes at home airport	337.98
	(114.65)
Deadweight Loss (from tax flights)	
Plane operating costs	26.58
	(16.92)
Pilot time	16.00
	(5.07)
Plane Costs + Pilot time	42.58
	(25.50)

Revenue and costs are calculated for each county in a taxing state, and the average and standard deviation are listed in the table. Revenue is calculated presuming all planes at an airport on assessment day are taxed, that planes which are located at their home airport on the assessment date are taxed, or that all planes pay tax to their home airport regardless of their location on the assessment date. Deadweight loss totals are calculated based on various assumptions about which components of tax flights should be considered socially wasteful.

Table 10: Validation: Tax Rolls and Tax Flights in KC Metro Area

(a) Tax Rolls and Tax Flights

Year	# with Home Airport		# On Tax Roll		# Tax Flights		%Tax Flight on Tax Roll	
	MO	KS	MO	KS	MO	KS	MO	KS
2009	570	191	329	112	183	57	10%	12%
2008	595	213	334	124	222	78	11%	9%
2007	605	212	328	121	230	75	7%	11%
2006	650	227	341	157	247	53	15%	11%
2005	725	194	383	153	269	30	8%	3%
2004	622	196	310	147	205	36	12%	14%

Note: First three panels are counts of aircraft, while the last panel is the percent of aircraft on the tax rolls engaged in tax flights. Totals exclude inactive planes and exempted planes (KS: business-owned planes and planes older than thirty years)

(b) Business-Owned (exempt in Kansas)

Year	# with Home Airport		# On Tax Roll		# Tax Flights		%Tax Flight on Tax Roll	
	MO	KS	MO	KS	MO	KS	MO	KS
2009	161	200	40	165	94	8	3%	88%
2008	164	193	40	177	91	12	5%	92%
2007	168	211	48	188	84	16	7%	88%
2006	185	230	45	209	111	15	8%	87%
2005	211	221	48	212	121	6	15%	100%
2004	171	213	38	208	99	10	11%	90%

Note: MO planes are a subset of those in (a); the KS planes are not in (a) since they are exempt. KS tax flights are based on observed interstate flights rather than from (5) and are Johnson County only (the county keeps business planes which register with the assessor on the tax roll even though they are exempted from taxes).

(c) Hysteresis among Planes on Tax Roll

Years on Tax Roll	% Planes	
	MO	KS
6	52%	61%
5	16%	12%
4	8%	9%
3	10%	9%
2	9%	6%
1	6%	3%

Table 11: Estimates: Covariates of Tax Flights and Evasion, KC Metro Area (logit)

Variable	Tax Flights	Missing from Tax Roll
Household Income		
Median Income (thousands $)	0.002	0.003
	(0.02)	(0.01)
% Income $\geq$ \$150k	0.007	0.005
	(0.003)	(0.002)
% Income $\geq$ \$200k	0.154	0.117
	(0.07)	(0.04)
% with self-employment income	-0.099	0.065
	(0.09)	(0.07)
% with non-wage income	0.015	0.023
	(0.01)	(0.01)
Owner-Occupied Housing		
Median Value (thousands $)	0.003	0.002
	(0.002)	(0.003)
% Value $\geq$ \$500k	0.021	0.018
	(0.01)	(0.01)
% Value $\geq$ \$1m	0.215	0.143
	(0.04)	(0.05)
N	3137	3137

The observation unit is a plane owner-year. The sample are plane-owners (excluding business- or government-owners) who are both living in and have planes located in the KC metro area. Each parameter is the result of a separate logit estimation using the dependent variable listed in the column header and the covariate in that row. The covariates are from Census Block Groups based on the owner's address as listed in the FAA *Aircraft Registry* (various years).

Figure 1: State Property Tax Policies for GA Aircraft

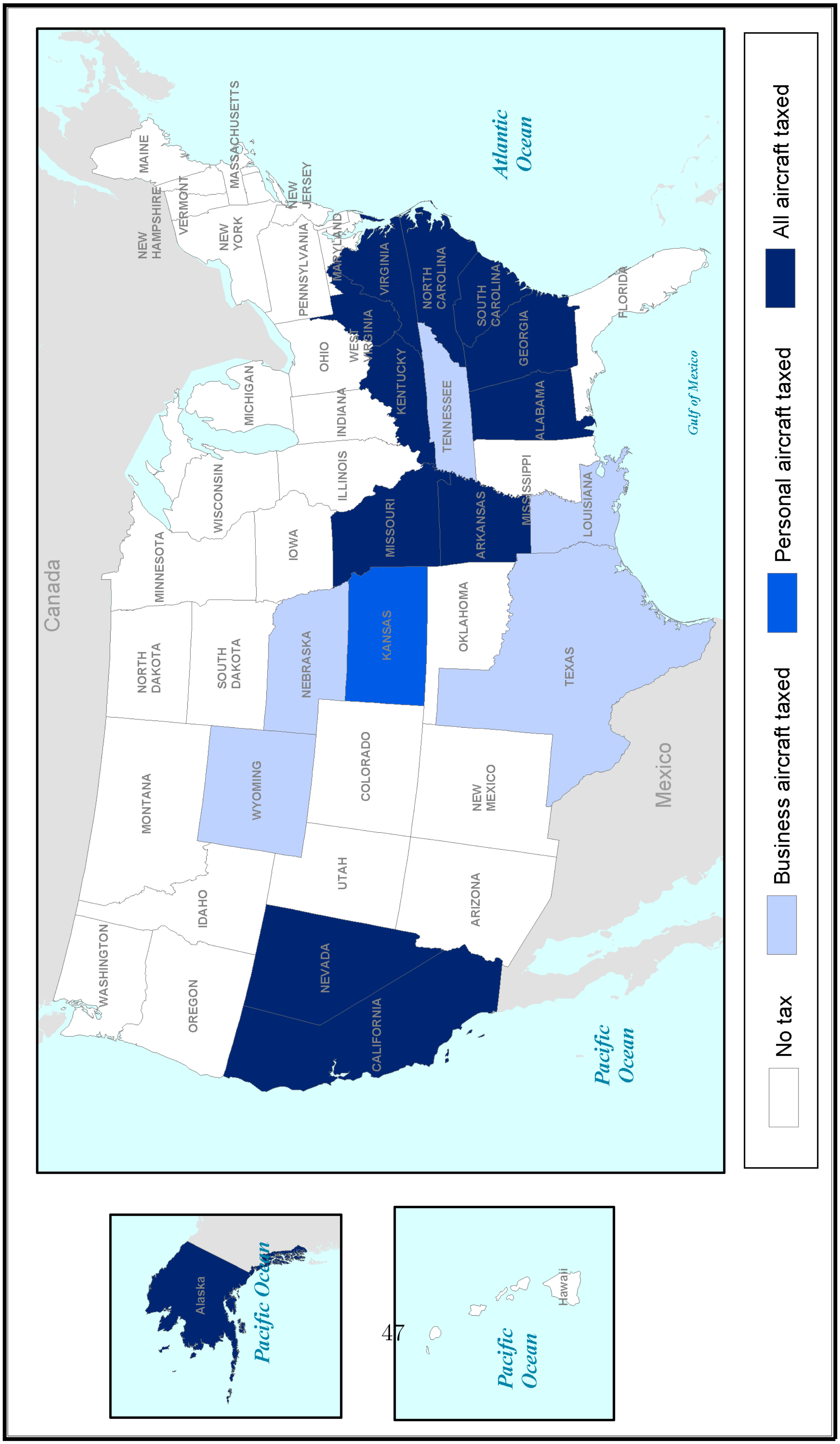


Figure 2: Identification: Geocoded Airports and Tax Units

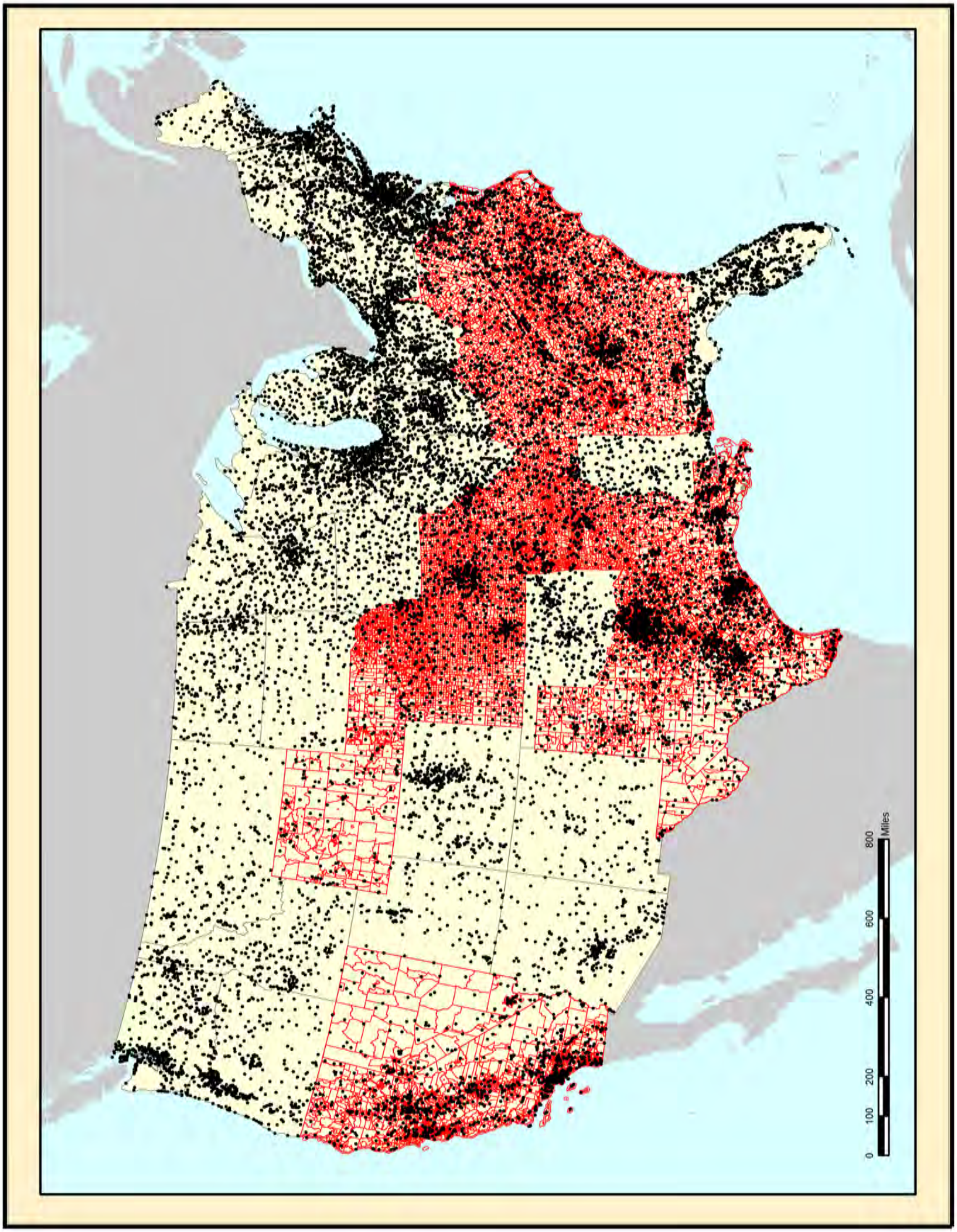
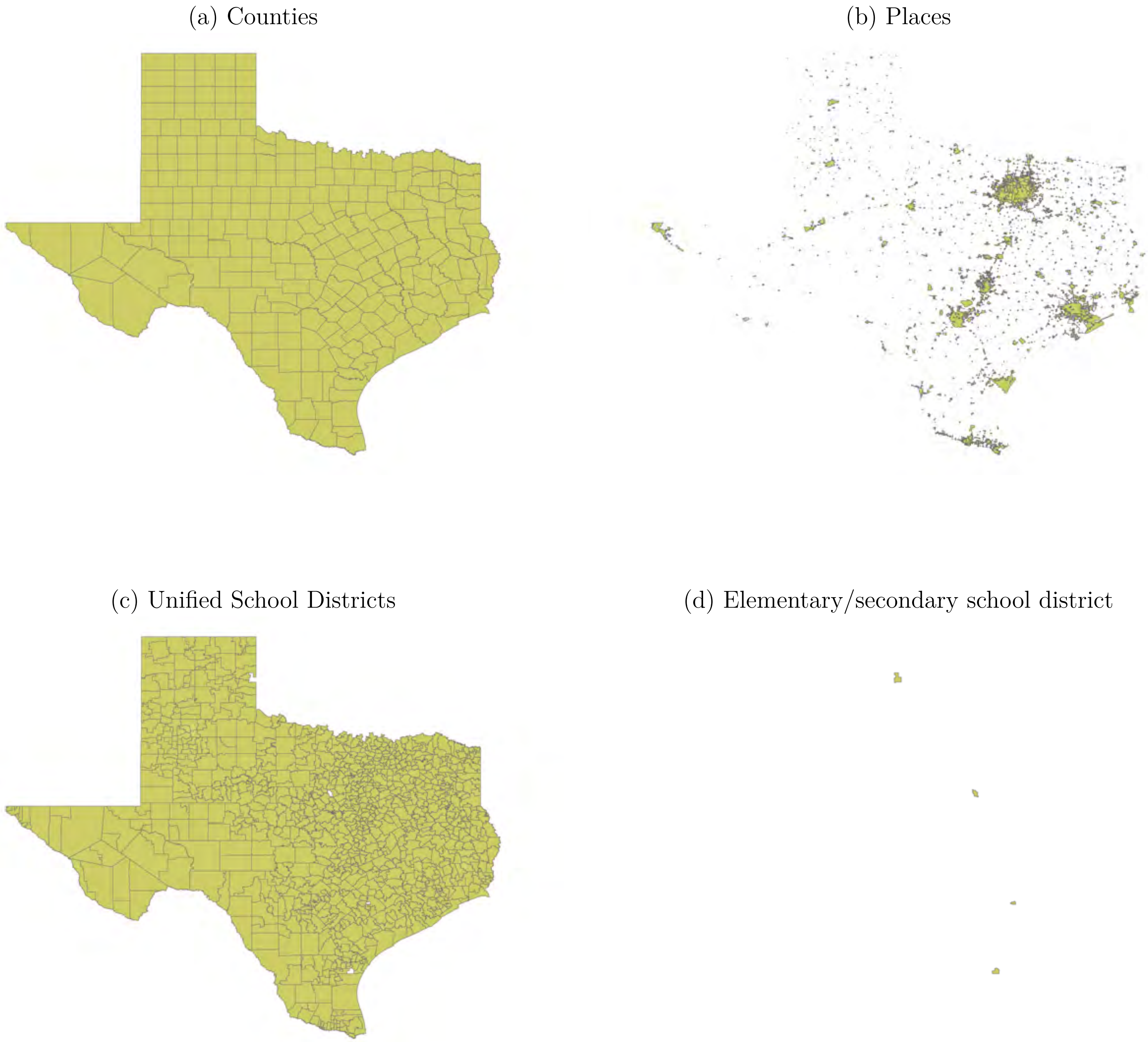


Figure 3: Texas: Overlapping Property Tax Units (excluding special districts; county sub-divisions have no tax authority)



(a) Counties

(b) Places

(c) Unified School Districts

(d) Elementary/secondary school district

Figure 4: Texas: 2009 Property Tax Rates

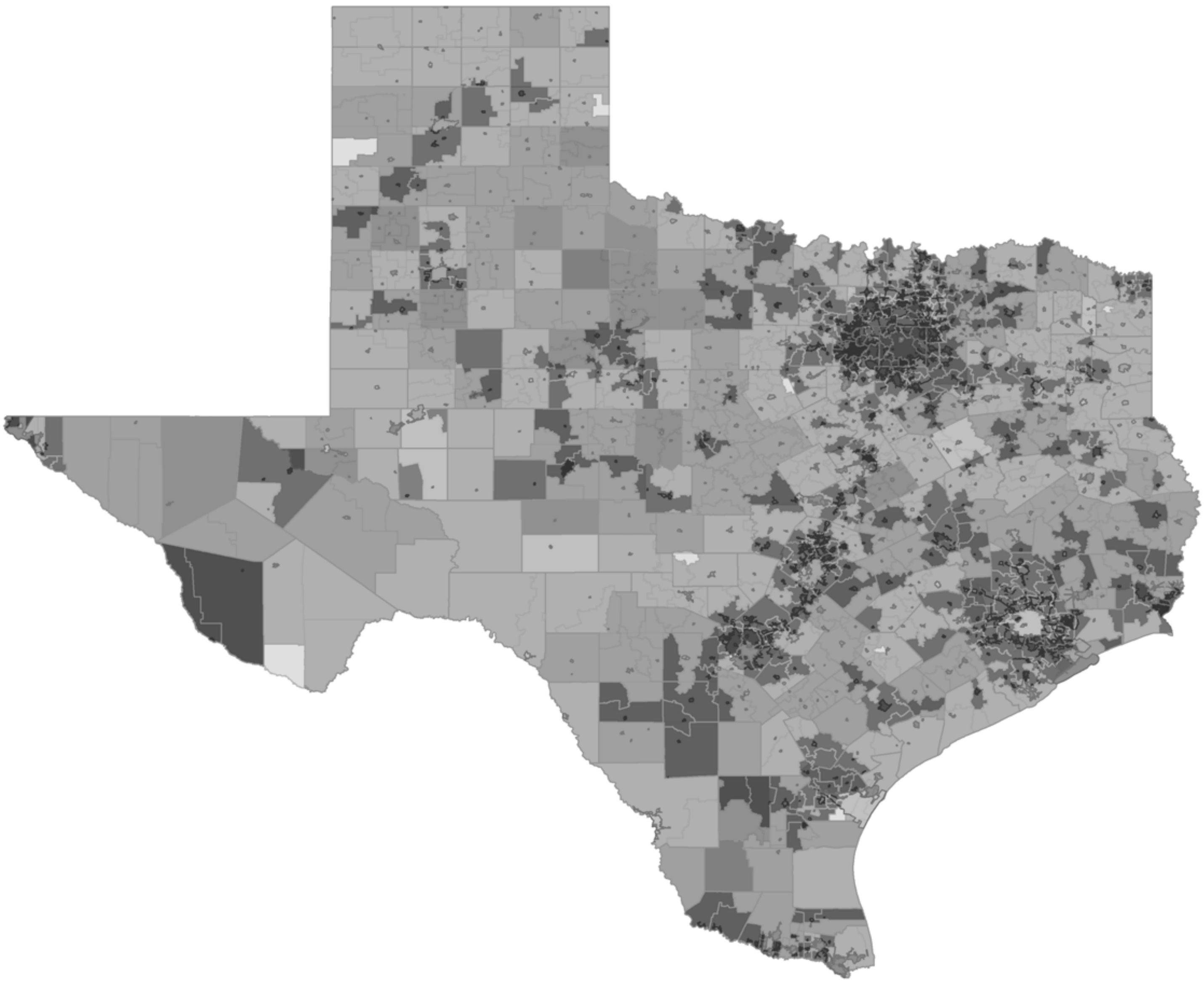


Figure 5: Texas: Geocoded Airports

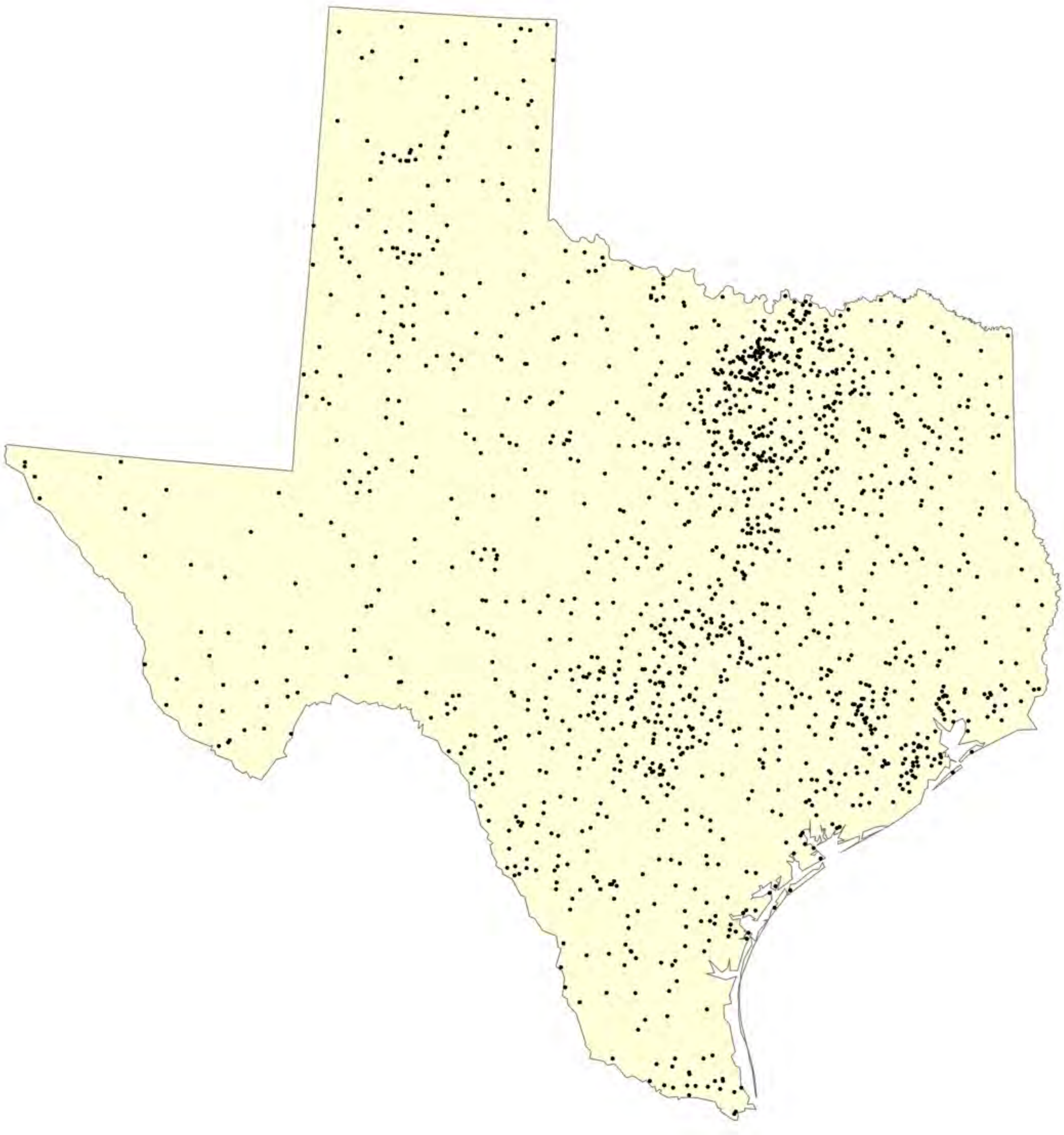


Figure 6: United States: Geocoded Airports (excludes AK and HI)

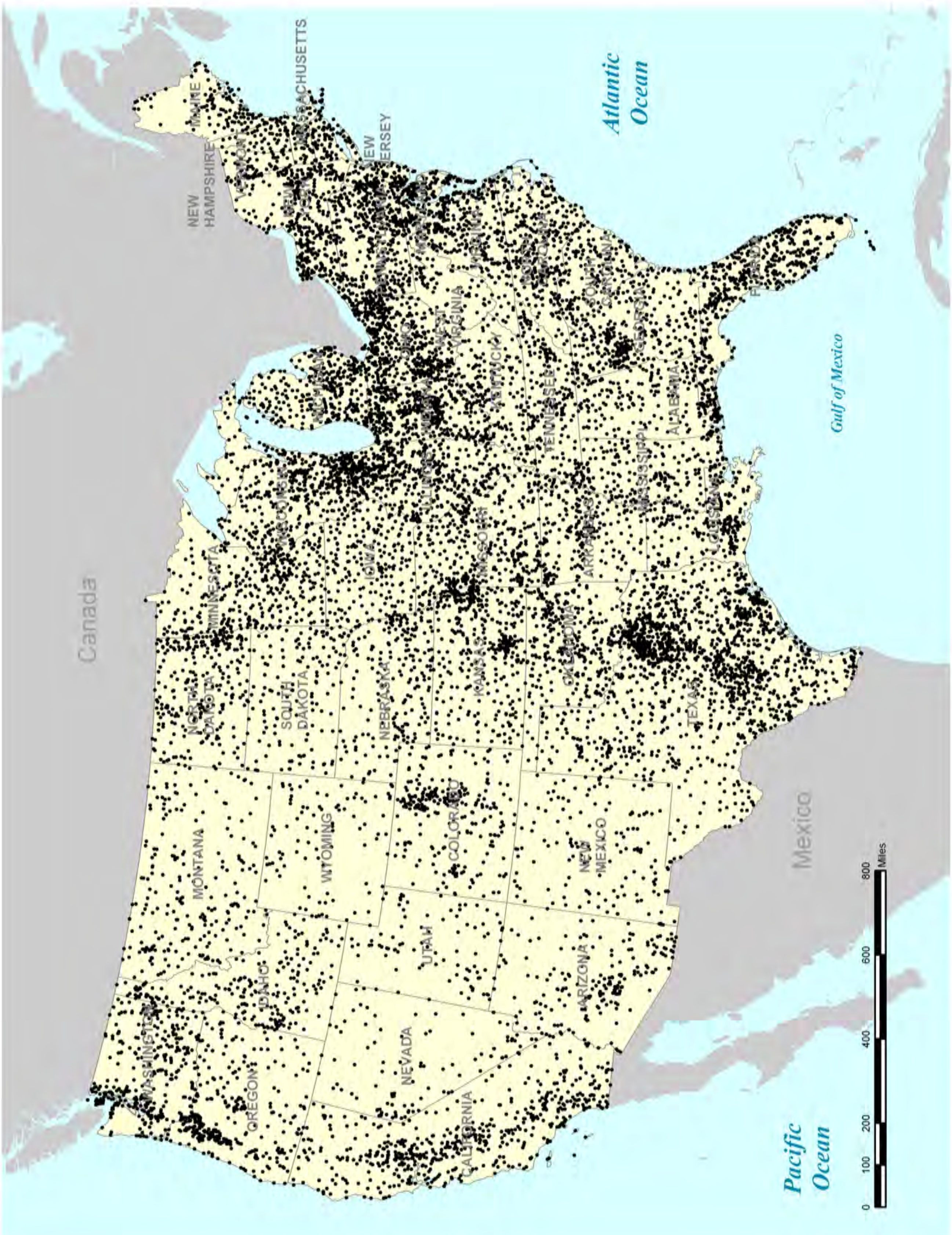


Figure 7: Geocoding Flow Chart

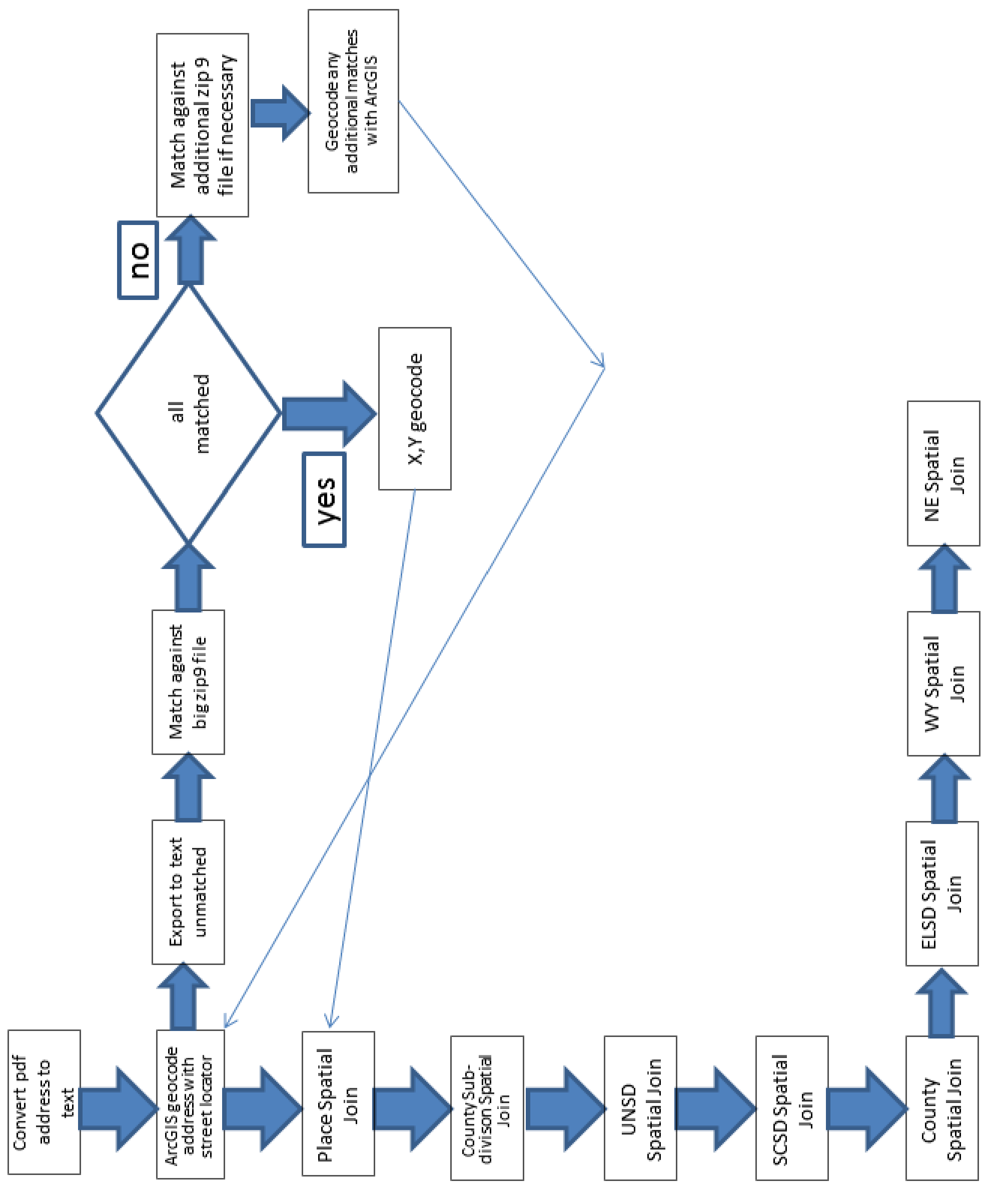


Figure 8: Flights By Week

week 1 = first week of year, ... week 52 = last week of year

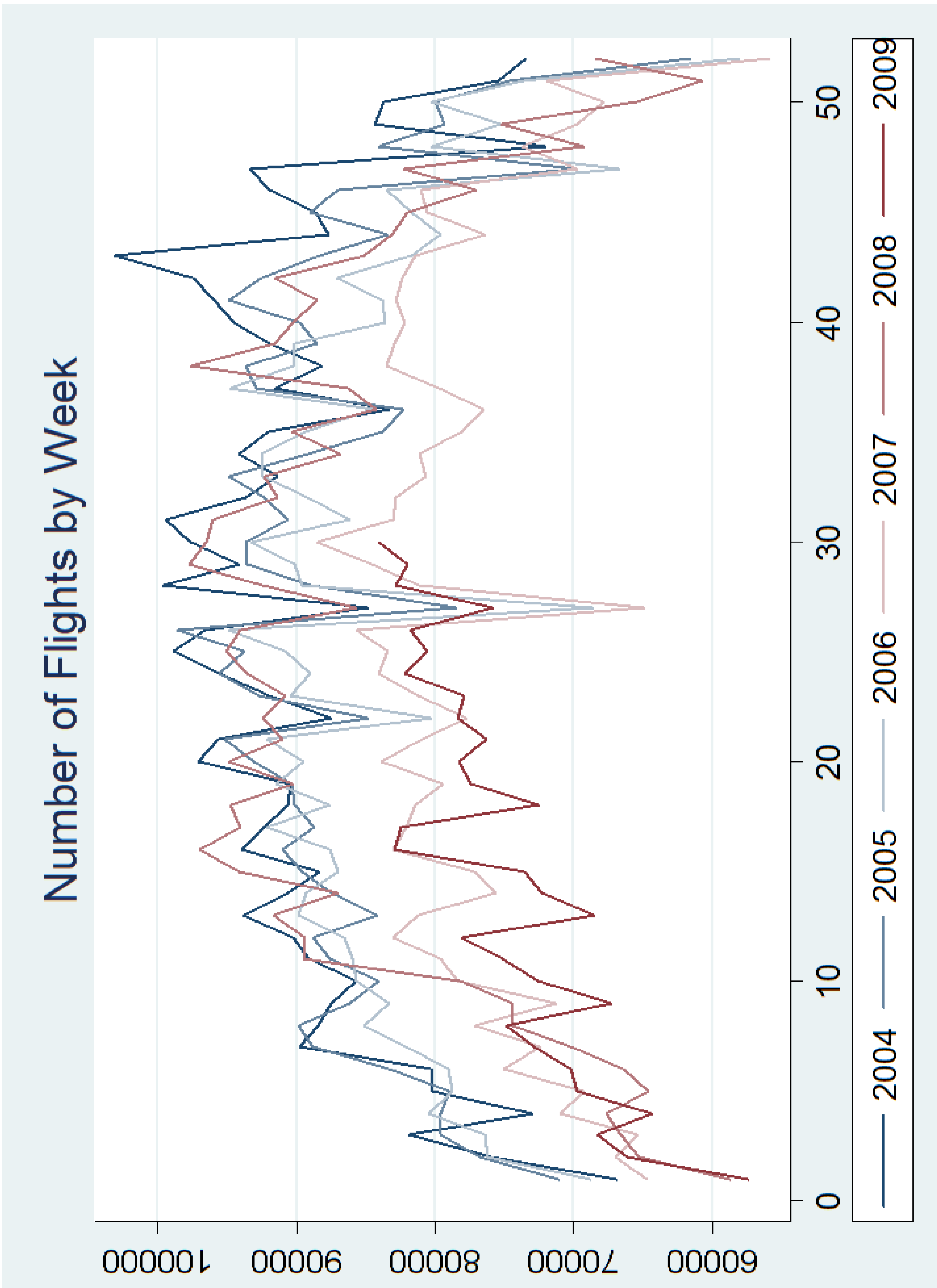


Figure 9: Imputed Tax Revenues by Week
week 1 = first week of year, ... week 52 = last week of year

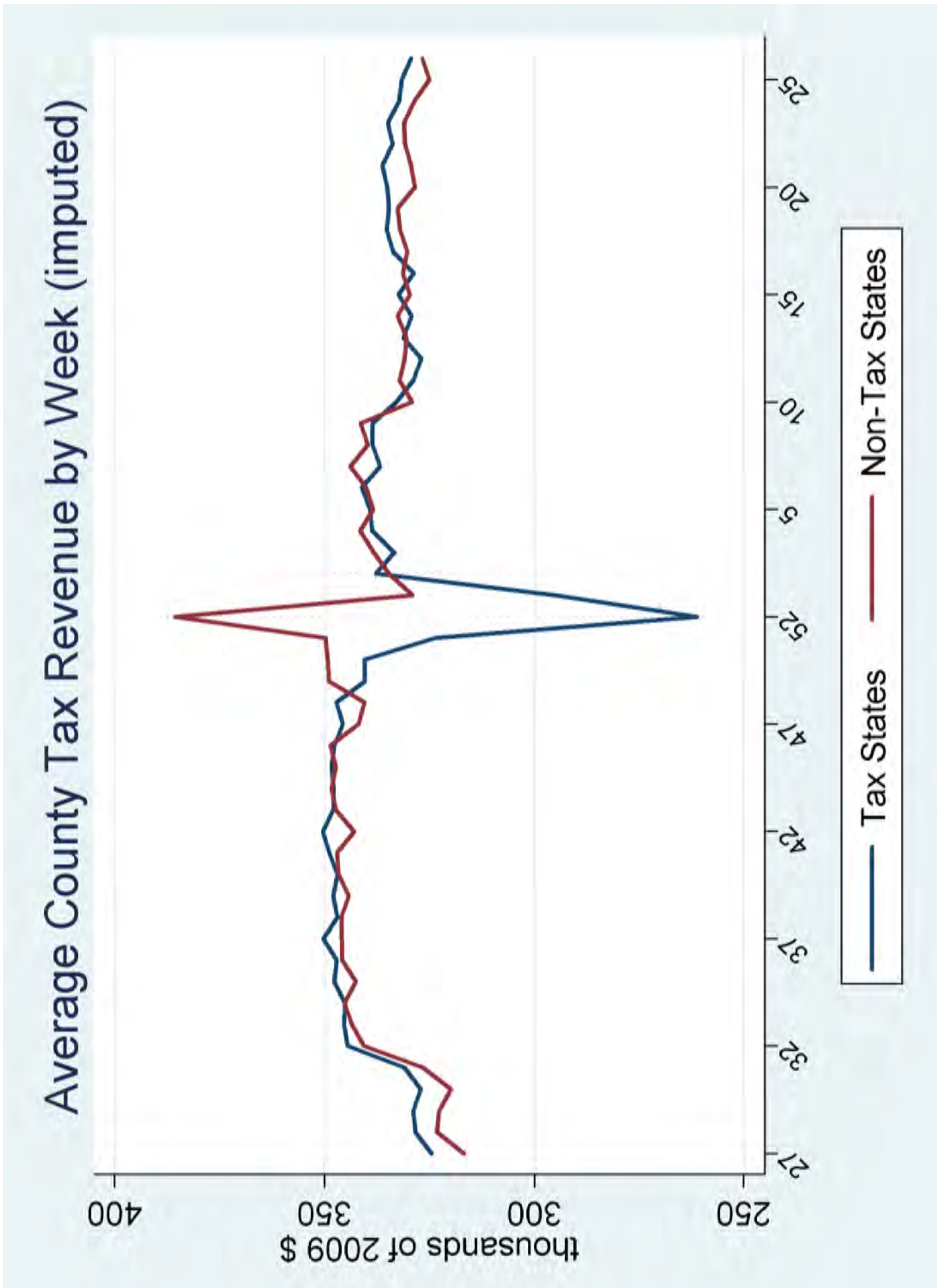
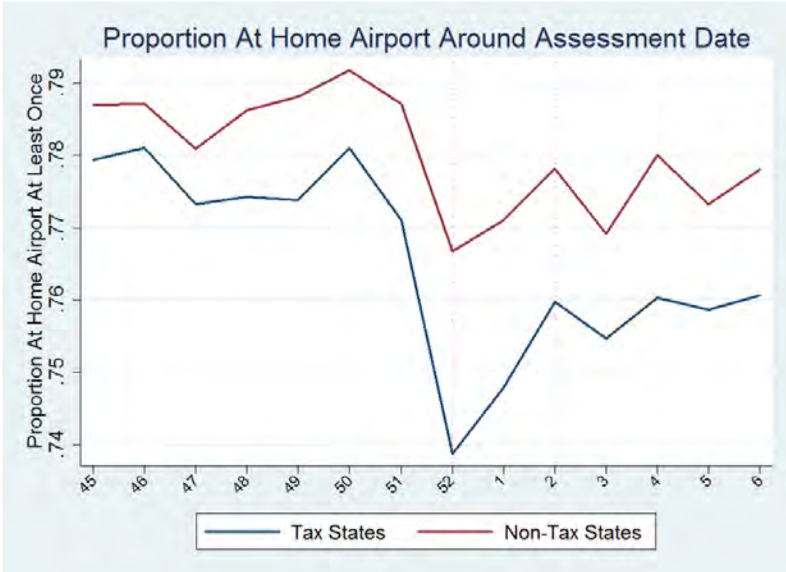


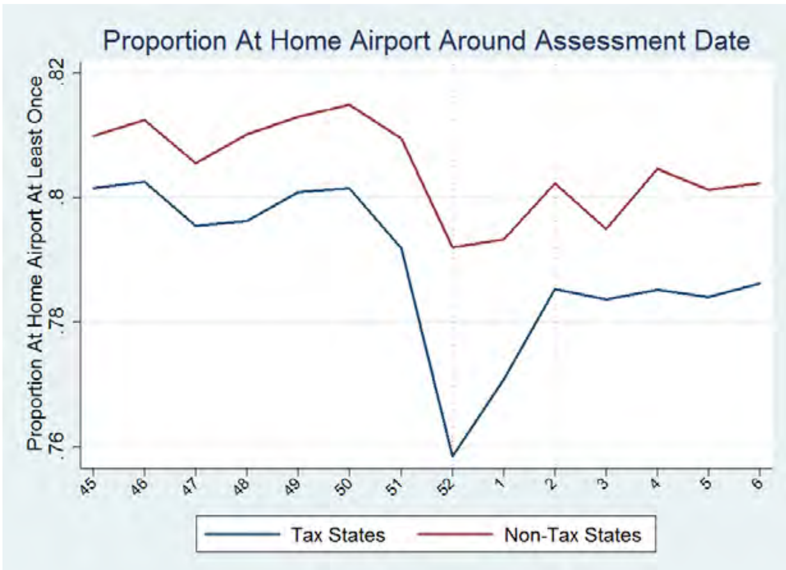
Figure 10: Home Airport Presence- In Neighborhood of Assessment Date

The three home airport definitions listed below are discussed in the text

(a) Hours on the Ground



(b) Flight Count



(c) Round-trips

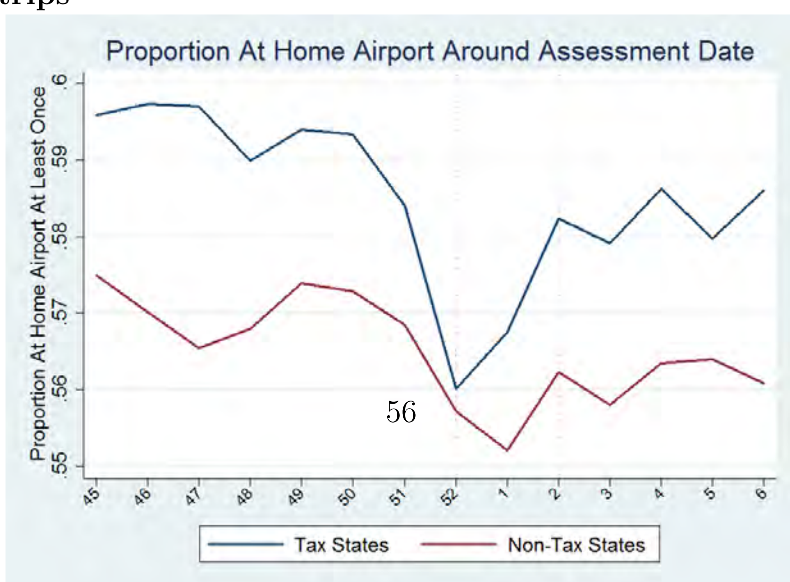


Figure 11: Interstate Flights - In Neighborhood of Assessment Date
Taxing States

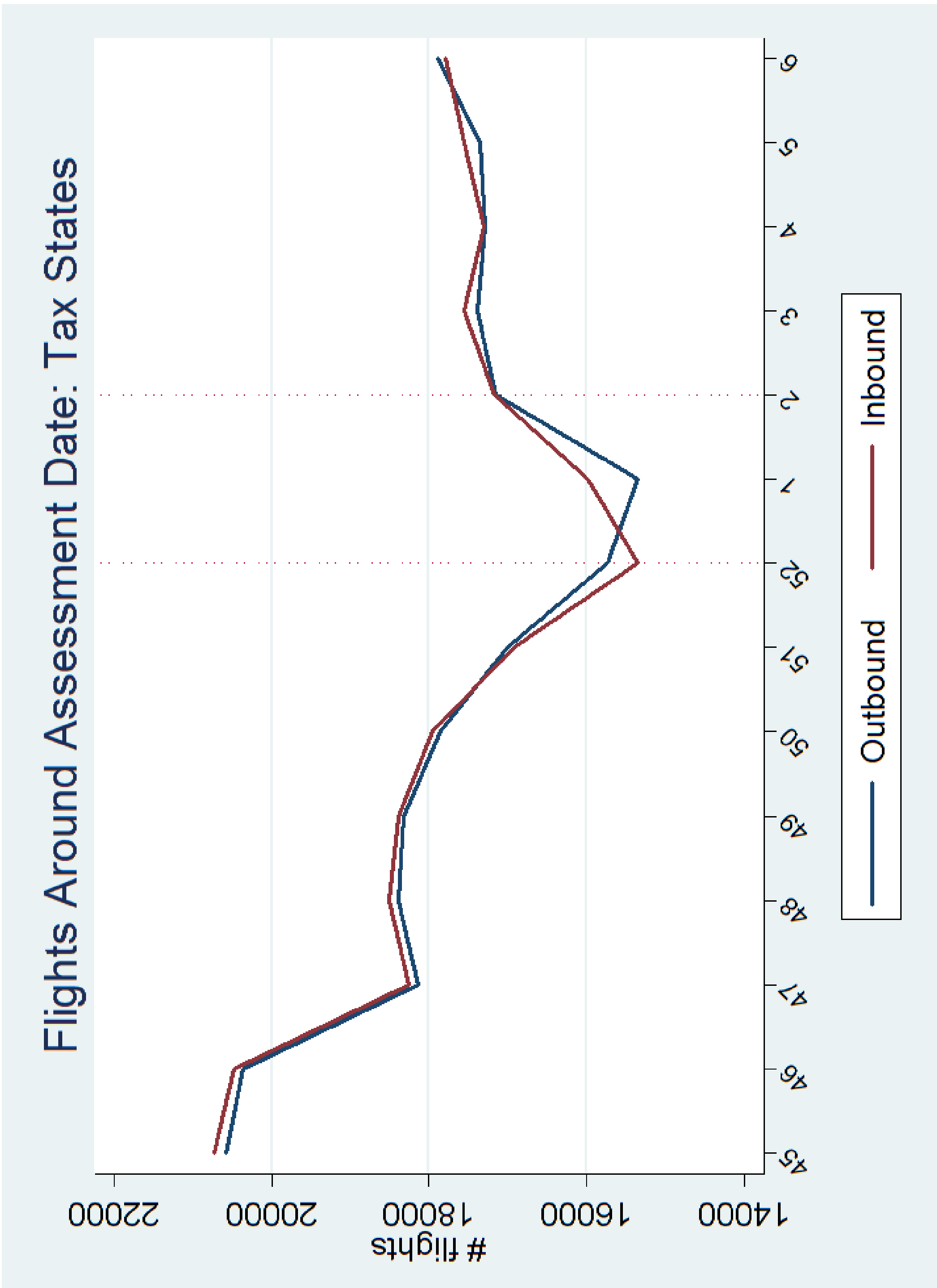


Figure 12: Interstate Flights - In Neighborhood of Assessment Date
Non-Taxing States

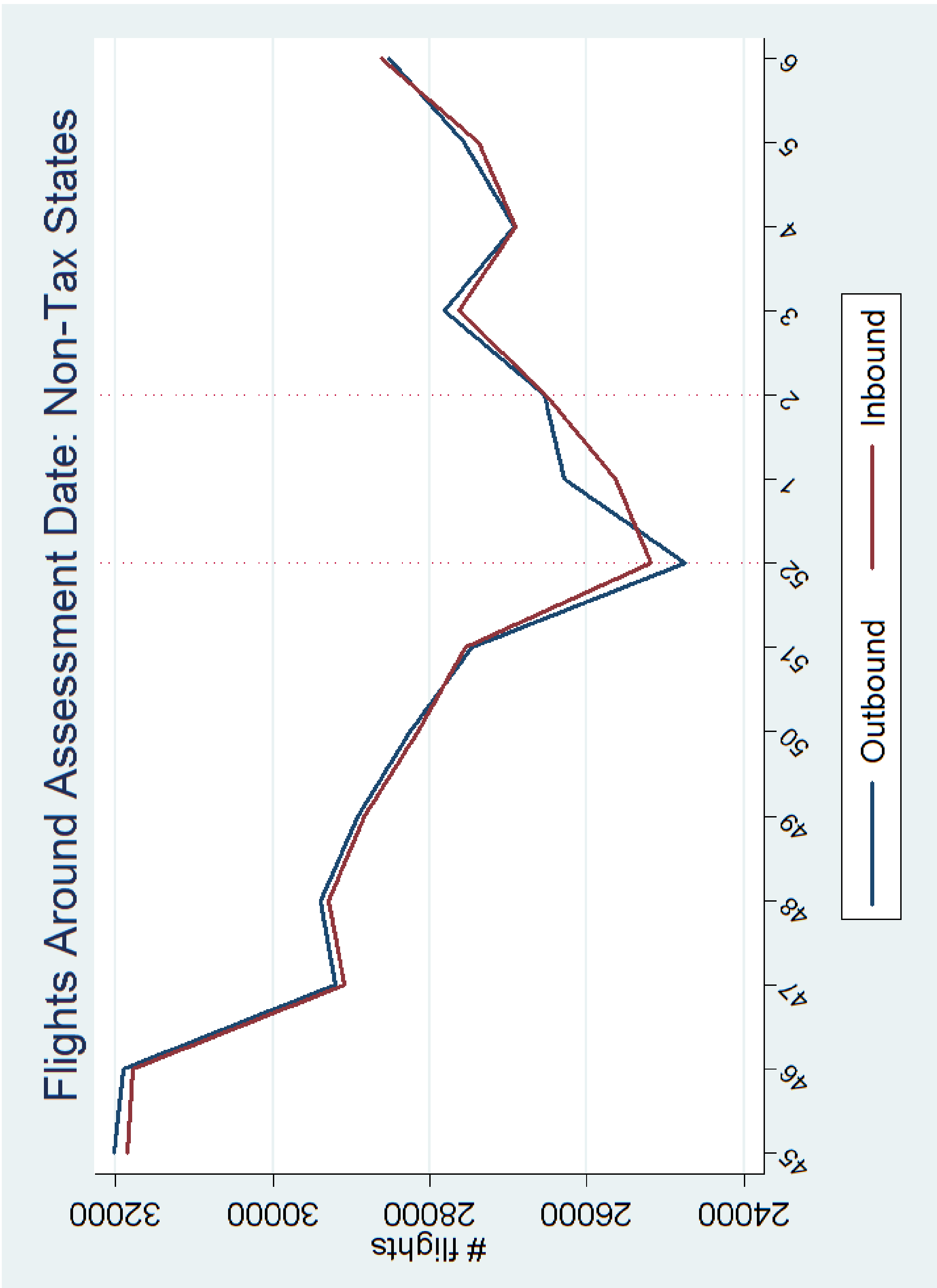


Figure 13: Interstate Flights - In Neighborhood of Assessment Date
Taxing States, by year

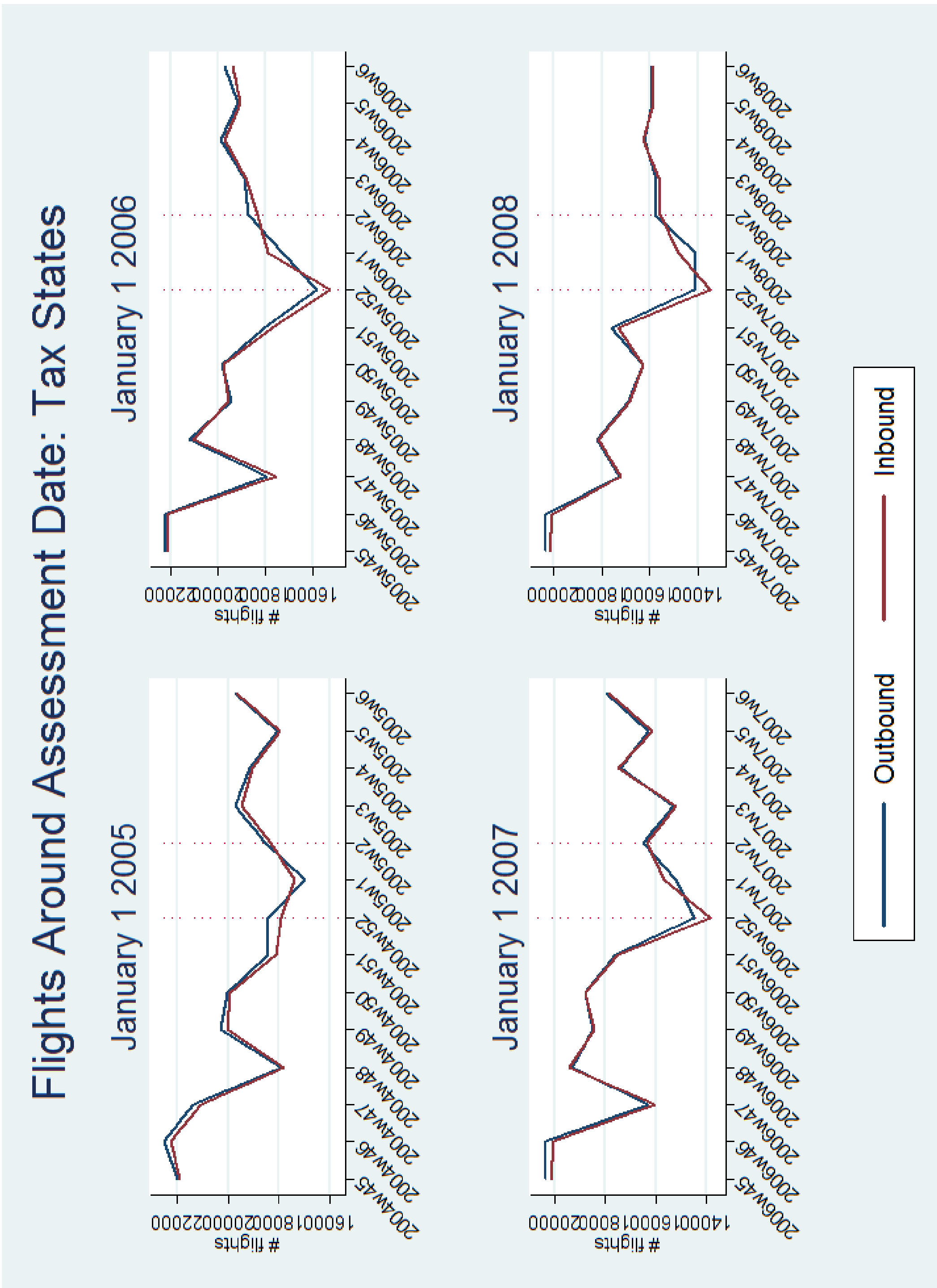
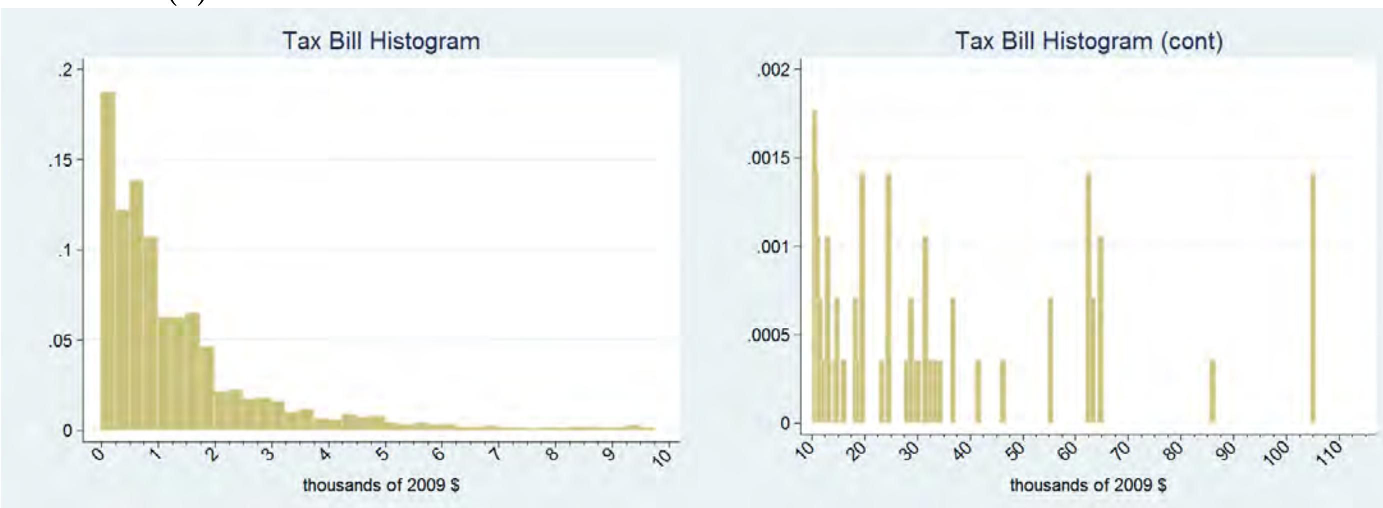
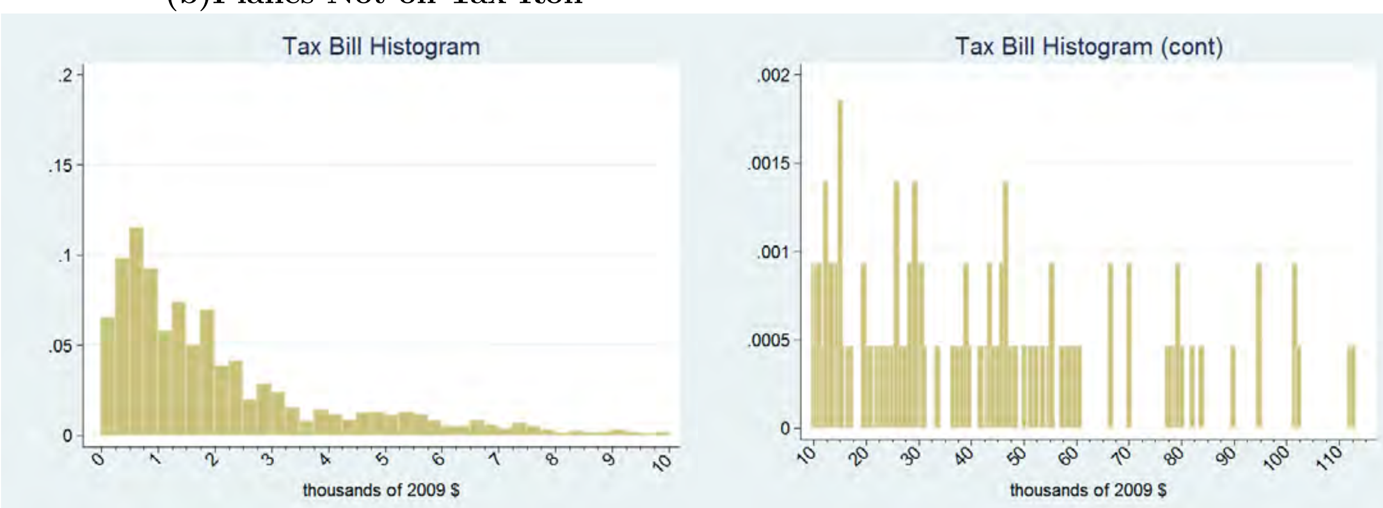


Figure 14: Kansas City Metro Area: Annual Property Tax Histogram
Higher tax values plotted on right figure with smaller y-axis scale

(a) Planes on Tax Roll



(b)Planes Not on Tax Roll



Online Data Appendix: Data Sources (Not For Publication)

Tax Flights

Koleman Strumpf

A. State Property Tax Treatment of General Aviation Aircraft

1. *National files*
   - CCH (2009), *2009 US Master Property Tax Tax Guide*, Wolter Kluwer Business. The 2000-2008 editions were also used to determine tax rule changes.
   - Conklin & de Decker (2009), *State Tax Guide for General Aviation*. Compact Disc, https://www.conklindd.com. The 2003-2008 editions and personal correspondence with Nel Stubbs (Conklin & de Decker VP/Co-Owner) were also used to determine tax rule changes.
   - Lawyer (2009), *Property Tax: Aircraft* and *Property Tax Estimates*, personal communication (this source prefers to remain unnamed but is a leading aviation attorney in the Midwest).
   - Phil Crowther (undated), *State Taxes of Aviation*, http://www.nbaa.org/member/admin/taxes/state/StateTaxes.pdf
   - Raymond Speciale (2003), *Aircraft Ownership: A Legal and Tax Guide*, McGraw-Hill.
   - National Business Aviation Industry (2010), *NBAA State Aviation Tax Report*, http://www.nbaa.org/admin/taxes/state/report.php
2. *State Files*
   - Alabama: *Alabama Department of Revenue: Property Tax FAQ*, http://www.revenue.alabama.gov/advalorem/faqs.html#pp; *Alabama Rules and Regulation, 810-4-1-.09, Valuation of aircraft*, http://www.ador.state.al.us/rules/810-4-1-.09.pdf
   - Alaska: *Property Tax in Alaska: Alaska Taxation and Assessment*, http://www.commerce.state.ak.us/dca/LOGON/tax/tax-prop.htm
   - Arkansas: Tom Atchley (Excise Tax Administrator)
   - California: California State Board of Equalization, *Assessor's Handbook Section 577: Assessment of General Aircraft* (2003), http://www.boe.ca.gov/proptaxes/pdf/ah577final2003.pdf. Note that Proposition 13 did not influence the assessment of personal property tax, which continues to be reassessed

annually (see California State Board of Equalization, *California Property Tax: An Overview* (Publication 29, August 2009), http://boe.ca.gov/proptaxes/pdf/pub29.pdf and Michael Coleman, *California Local Government Finance Almanac* (2009), http://www.californiacityfinance.com/#PROPTAX).

- Georgia: *Property Tax Guide For The Georgia Taxpayer*, https://etax.dor.ga.gov/PTD/adm/taxguide/gen/assessment.aspx and *County Ad Valorem Tax Facts*, https://etax.dor.ga.gov/PTD/county/index.aspx.

- Kansas: *Kansas Personal Property Summary*, http://www.ksrevenue.org/pdf/ppsumm.pdf; *Personal Property Valuation Guide*, http://www.ksrevenue.org/pdf/PPVG.pdf; *Kansas Statutes*, http://www.kslegislature.org/li/statute/.

- Kentucky: Bill Lawson (Property Tax Division of Kentucky Department of Revenue); various Kentucky tax officials; *Personal Property Tax Forms and Instructions*, http://revenue.ky.gov/NR/rdonlyres/4BC33A9F-F091-414A-A715-37F3C224482D/0/62A5001109revised21110.pdf

- Louisiana: *Louisiana Property Tax Basics*, http://www.lafayetteassessor.com/TopicsPDFs/Louisiana%20Property%20Tax%20Basics%20booklet%203.pdf; *Louisiana Tax Commission Manual*, http://www.latax.state.la.us/Menu_RulesRegulations/RulesRegulations.aspx; Paulette Jackson (Louisiana Legislative Auditor's Office)

- Missouri: *Missouri Revised Statutes: Chapter 155 Taxation of Aircraft* and *Chapter 137 Assessment and Levy of Property Taxes*, http://www.moga.mo.gov/STATUTES/STATUTES.HTM

- Nebraska: Elaine Thompson (Tax Specialist Senior, Property Assessment Division, Department of Revenue); Laz Flores (Tax Analyst/Education Coordinator, Property Assessment Division, Department of Revenue); *Property Assessment Division Annual Reports*, http://www.revenue.ne.gov/PAD/research/annual_reports.html

- Nevada: *Aircraft Assessment*, http://www.carson.org/index.aspx?page=1359; Dave Dawley (Assessor for Carson City)

- North Carolina: *2007 Personal Property Appraisal and Assessment Manual*, http://www.dornc.com/publications/appraisal_assessment.html; *Personal Property Audit Seminar Manual*, http://www.dornc.com/publications/audit_manual.pdf; *Cost and Depreciation Schedule*, http://www.dornc.com/publications/property.html; Gregg Martin (Property Tax Division of NC Department of Revenue)

- South Carolina: *Homeowner's Guide to Property Taxes in South Carolina*, http://www.sctax.org/publications/propguid99.html; Sharon West (Auditor, Spartanburg County)

- Tennessee: *Tennessee Codes Annotated: Title 67 Taxes And Licenses*, http://www.lexisnexis.com/hottopics/tncode/; Shannon Tucker (Associate Assessment Analyst, Comptroller of the Treasury, Office of State Assessed Properties)

- Texas: *A Handbook of Texas Property Tax Rules*, http://www.window.state.tx.us/taxinfo/proptax/proptaxrules.pdf; *Property Tax Calendar*, http://www.window.state.tx.us/taxinfo/proptax/taxcalendar/2009calendar.pdf; *Texas Property Tax Code* and *Texas Property Tax Laws*, http://www.window.state.tx.us/taxinfo/proptax/archives.html

- Virginia: Deborah Midgett (Chief Deputy, Accomack County Commissioner of the Revenue); Steve Kulp (Cooper Center); *Code of Virginia: Title 58.1 - TAXATION. Chapter 35 - Tangible Personal Property, Machinery and Tools and Merchants' Capital*, http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+TOC58010000035000000000000

- West Virginia: *Property Taxes*, http://www.state.wv.us/taxrev/97taxlaws/97tl_property.pdf; *West Virginia Tax Laws*, http://www.state.wv.us/taxrev/publications/taxLawReport.pdf; *Guide for County Assessors: State of West Virginia*, http://www.state.wv.us/taxrev/ptdweb/misc/Assessor%20Guide%202007%20.pdf; *Guidebook to WV Taxes (Chapter 6: Property Tax)*, http://www.jimsturgeon.com/WVTaxGuide/Ch6WVTG2011Final.pdf; *West Virginia Code: Chapter 11. Taxation*, http://www.legis.state.wv.us/WVCODE/Code.cfm?chap=11&art=1.

- Wyoming: David Chapman (Manager of Technical Services Group, Wyoming Department of Revenue Property Tax Division); Joyln Stotts (Appraiser, Wyoming Department of Revenue Property Tax Division); Jeness Saxton (Deputy Assessor, Sublette County Assessor Office); *Tax Information*, http://www.dot.state.wy.us/wydot/aeronautics/information/frequent_questions

B. Property Tax Rates

1. *National files*
   - Partial list of local tax rates: Lincoln Institute (2010). *Significant Features of Property Tax.* George Washington Institute of Public Policy. http://www.lincolninst.edu/subcenters/significant-features-property-tax/Report_TaxRates.aspx
   - State average property tax rates on general aviation aircraft: Lawyer (2009), *Property Tax Estimates*, personal communication (this source prefers to remain unnamed but is a leading aviation attorney in the Midwest).
   - Median county property tax rates for 2005-2009: These are 5-year estimates based on data collected between January 2005 and December 2009 (annual values for this period are only available for counties with populations of at least 65,000). The rates are based on tables B25103 (Mortgage Status by Median Real Estate Taxes Paid), B25119 (Median Household Income in the Past 12 Months by Tenure: Owner Occupied), B25077 (Median Value for Owner-Occupied Housing Unit) in the US Census' A*merican Community Survey*, via American FactFinder (http://factfinder.census.gov/jsp/saff/SAFFInfo.jsp?_content=acs_guidance_2009.html) and Summary File through Data Ferret (http://dataferrett.census.gov).
2. *State Files*
   - Alabama: Alabama Department of Revenue, *County Millage Rates* (various years), http://www.ador.state.al.us/advalorem/index.html
   - Alaska: Alaska Office of the State Assessor, *Alaska Taxable* (various years), http://www.dced.state.ak.us/dca/osa/osa_home.htm

- Arkansas: Arkansas Assessment Coordination Department, *Millage Report* (various years), http://www.arkansas.gov/acd/statewide_values_rates.html. Taxing Units Value, Rate & Tax (2002-2006), http://web.archive.org/web/20080906112157/http://www.arkansas.gov/acd/statewide_values_rates.html. *1995-2005 Millage Rates*, http://www.arkansas.gov/acd/publications.html. Rates missing from these files come from personal communication with Faye Tate (Deputy Director, Arkansas Assessment Coordination Department).

- California: California allows sub-county governments to set property tax rates, rates vary over the tens of thousands of tax rate areas (TRAs), but as of 2010 there is no centralized collection of these data nor are all parcels digitally mapped (this was confirmed with Ralph Davis, Research Manager at California's Board of Equalization and with Michael Coleman, Fiscal Policy Advisor, League of California Cities). Instead average rates for each county are used. This is not an unreasonable assumption given the Proposition 13 tax limit, which generally limits total rates to one percent (for example additional taxes can be levied to pay for bonds, so long as a super-majority of local residents approve; see http://www.boe.ca.gov/proptaxes/faqs/generalinfo.htm#2). County average rates come from California State Board of Equalization, *Annual Reports* (various years), http://www.boe.ca.gov/annual/annualrpts.htm

- Georgia: Georgia Department of Revenue: The Local Government Services Division, *Georgia County Ad Valorem Tax Digest: Millage Rates* (various years), https://etax.dor.ga.gov/ptd/cds/csheets/millrate.aspx

- Kansas: League of Kansas Municipalities, *Kansas Tax Rate Book*, (various years), Insert in *Kansas Government Journal* and personal communication (Excel file); *Kansas Township Levies* (2011), personal communication from Peggy Huard (Appraiser II, Abstract Section Division of Property Valuation, Kansas Department of Revenue)

- Kentucky: Department of Revenue: Office of Property Valuation, *Commonwealth of Kentucky Property Tax Rates* (various years), http://revenue.ky.gov/newsroom/publications.htm. Tax rates on general aviation were based on conversations with Bill Lawson (Property Tax Division of Kentucky Department of Revenue) and various Kentucky tax officials.

- Louisiana: Office of the Legislative Auditor, *Parish Pension Report* (various years), http://app1.lla.state.la.us/reassessment.nsf/fmpprr; Office of the Legislative Auditor, *Maximum Millage Report* (various years), http://app1.lla.state.la.us/reassessment.nsf/fmMMRR; Louisiana Tax Commission, *Annual/Biennial Report* (various years), http://www.latax.state.la.us/Menu_AnnualReports/AnnualReports.aspx and hard copies. Interpreting the rates in these documents was based on conversations with Paulette Jackson (Louisiana Legislative Auditor's Office) and Terry Calendar (Louisiana Tax Commission).

- Missouri: Office of the State Auditor, *Review of Property Tax Rates* (various years), http://www.auditor.mo.gov/auditreports/propertytaxrates.htm

- Nebraska: *Nebraska Reference List of Taxing Entities, by county, for years 2001 to 2009 (Excel file)*, personal communication from Elaine Thompson (Tax Specialist Senior, Property Assessment Division, Department of Revenue); *Nebraska Average Tax Rates, value & taxes, by county, for years 1993 to 2009 (Excel file)*, personal communication from Elaine Thompson; Property Assessment Division, *Annual Reports* (various years), http://www.revenue.ne.gov/PAD/research/annual_reports.html.

- Nevada: Nevada Department of Taxation, *Property Tax Rates for Nevada Local Governments ("Nevada Redbook") (Excel file)* (various years), personal communication from Tom Gransbery (Division of Assessment Standards).

- North Carolina: North Carolina Department of Revenue, *County and Municipal Property Tax Rates and Year of Most Recent Revaluation* (various years),http://www.dornc.com/publications/propertyrates.html.

- South Carolina: South Carolina Association of Counties, *Property Tax Rates By County in South Carolina* (various years), http://sccommerce.com/data-resources.

- Tennessee: Tennessee Comptroller of the Treasury: Division of Property Assessments, *Tennessee Property Tax Rates* (various years), http://www.comptroller1.state.tn.us/PAnew/.

- Texas: Texas Comptroller of Public Accounts, *County and ISD Tax Rates by County* (various years), http://www.window.state.tx.us/taxinfo/proptax/; Texas Comptroller of Public Accounts, *Annual Property Tax Report* (various years), http://www.window.state.tx.us/taxinfo/proptax/archives.html; Texas Comptroller of Public Accounts, *Property Tax Rates by County (Excel file)* (various years), http://www.window.state.tx.us/taxinfo/proptax/archives.html; *Rates and Levies* (various years), personal communication from Dawn Albright (Open Records Coordinator, Property Tax Assistance Division, Texas Comptroller of Public Accounts).

- Virginia: Weldon Cooper Center for Economic and Policy Studies, *Virginia Local Tax Rates* (various years), http://www.coopercenter.org/econ/taxrates; personal communication from Steve Kulp (Cooper Center).

- West Virginia: Local Government Services Division of the West Virginia State Auditor's Office, *Rates of Levy: State, County, School and Municipal* (various years), http://www.wvsao.gov/localgovernment/Reports.aspx and personal communication from Joyce Ferrebee (West Virginia State Auditor's Office).

- Wyoming: Wyoming Department of Revenue, *Property Tax Mill Levy by Tax District* (various years), http://revenue.state.wy.us/PortalVBVS/DesktopDefault.aspx?tabindex=2&tabid=10; Wyoming CAMA, *Wyoming Tax District Information: Map & GIS Data* (various years), http://cama.wyoming.gov/DISTRICTS/MAPS_ONLINEDOCUMENTS/ShowMAPS_ONLINEDOCUMENTSTable.aspx; Ad Valorem Tax Division of the Wyoming Department of Revenue, *Tax District Booklet* (various years), personal communication from David Chapman (Manager of Technical Services Group, Wyoming Department of Revenue Property Tax Division).

C. Costs: Variable Operating Cost, Cost of Time

The cost of a tax flight is primarily expenses associated with flying the plane to a non-taxing airport. The first component is variable operating which is calculated from variable cost per hour times flying time. Variable cost per hour is specific to each aircraft modeland comes from personal correspondence with David

Wyndham (Conklin & de Decker VP/Co-Owner). These are calculated annually for includes all factors associated with flying a plane including fuel, maintenance reserves for routine maintenance, engine/propeller/APU reserves, and miscellaneous expenses. These are adjusted to reflect regional and higher frequency variation in aviation fuel (I use the proportion of variable cost per hour due to aviation found at http://www.planequest.com, http://www.what2fly.com, and http://www.audriesaircraftanalysis.com/). There are two main kinds of fuel for general aviation planes. Avgas is used to power reciprocating (piston) engines, and jet fuel is used with gas turbine (turboprop and turbofan) engines. Certain planes can also use mogas (automotive gasoline). The price of these fuels varied substantially over the sample period: jet fuel began at about $1 a gallon in January 2004, spiked from $2 to $3 in September 2005, fell back to around $2 in October 2005 where it remained for a year before rising to $4 in September 2008, and then collapsing to less than $1.50 by December 2008 (US Energy Administration, Petroleum and Other Liquids, Kerosene-Type Jet Fuel, US Gulf Coast, http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPJK_PF4_RGC_DPG&f=D). There is also variation across space with average Avgas prices often varying by ten percent across different regions of the country. I use data from AirNav (Fuel price report, http://www.airnav.com/fuel/report.html) which reports average Avgas (100LL), Jet (Jet A), and Mogas prices for each of nine regions of the U.S. I get data via the Internet Archive which provides roughly monthly scrapes for the full 2004-2009 sample period.

To calculate operating costs this factor must be multiplied by flying time, which is calculated from speed and distance. For speed I use normal cruising speed, the recommended cruising speed from the manufacturer (this is usually between the max and long range cruise speeds; for some aircraft normal speed is not listed in which case max cruise speed is used). This value is plane model specific and comes from personal correspondence with David Wyndham (cited above). For distance the goal is to find the closest non-taxing airport which can accommodate a given plane. To do this, I cycle through each airport and find the closest airport in another state which has a runway of sufficient length to accommodate each model. I use the Stata module `geonear` to identify the nearest airport and to calculate the geodetic distance. The airport coordinates and runway length are drawn from sources in the next subsection, and the required runway length for each plane model are from landing distances in personal correspondence with David Wyndham (cited above), FAA (2010), and OurAirports (the latter two sources are listed in the next sub-section).

The other component of costs is the opportunity cost of the pilot's time. I base this on the time in the air only (time in the ground in between flights can be used for leisure), which is calculated using the procedure listed above. For the value of time I use the monthly values from the CES series CES0500000008 "Average hourly earnings of production and nonsupervisory employees, total private, seasonally adjusted" (BLS, 2013, "Current Employment Statistics - CES (National): historical data for the 'B' tables of the Employment Situation News Release," https://www.bls.gov/ces/cesbtabs.htm). These values are slightly lower those listed in the related series CES0500000003 "Average hourly earnings of all employees, total private, seasonally adjusted" (which only starts in March 2006): the marginal effect of costs is generally robust to using the latter series when available.

D. Airports

For each airport two items is needed: the airport identifier, the three or four letter code which pilots use to label it, and the geographic coordinates, the longitude and latitude. This task is complicated because there are three identifier systems (FAA, ICAO, IATA), the codes of several airports change, and there are discrepancies or missing information about the geographic coordinates. Multiple sources were used to help mitigate these issues.

- NFDC Airport Facilities file, FAA's *Form 5010: Airport Master Record* (2010)
- AirNav Airport information (including all public and private use airports as well as the list of identifier changes), `http://www.airnav.com/airports/`
- OurAirports, `http://www.ourairports.com/data/`
- FlightAware Airport information, `http://flightaware.com`
- FlightView Airport file, personal correspondence.

E. Kansas City Metropolitan Area

The first item which is needed are tax rolls for each county. These are annual files and include the tax payer name, address, plane type (and sometimes valuation), and tax paid for each plane on which property taxes were paid. The sources are:

- Ryan Kath (2011), Various Missouri county tax rolls used for "Investigation finds dozens of plane owners not paying taxes, costing local governments big bucks", personal communication.
- Douglas County, KS: Karla Grosdidier (2011), Personal Property Appraiser Douglas County Appraisers Office, personal communication.
- Johnson County, KS: Cynthia Dunham (2009), Assistant County Counselor Johnson County Legal Department, personal communication.
- Wyandotte County, KS: Wyandotte Treasurer office (2009), personal communication.
- Cass County, MO: Tammy (2011), Cass County Collector office, personal communication.
- Clay County, MO: scrapes from Clay County Collector website (2011), http://collector.claycogov.com
- Jackson County, MO: Dan Ferguson (2011), Public Information Officer, personal communication.
- Platte County, MO: Mary Simpson (2011), Platte County Assessor's Office, personal communication.

The second item is the Census Block Group data. This is the smallest geographic area containing demographic data from the Summary File 3 (long form questionnaires from a sample of 1 in 6 households). For all the Census Block Groups in the metro area, I get 2000 demographic data from the Census' *American FactFinder* (http://factfinder2.census.gov/) and shape files from Census' *TIGER/Line Shapefile* (various years). I supplement the demographic data with the Census' 2005-2009 A*merican Community Survey* (http://www.census.gov/acs/www/). Note that only five year ACS files have data for all areas, and 2005-2009 is the earliest year for this report. With the shape files, I geolocate all addresses and airports and in the metro area to Census Block Groups using the procedure discussed in the main text.