The Other Green Economy:
An Estimate of the Potential Revenue Generated by a Legally Taxed and Regulated Marijuana Market

by

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Abstract

In the current political and economic climate, drug policy reform has recently become more prominent in the national political discourse. Specifically with regard to marijuana, there have been increasing calls in recent weeks and months to begin to consider the decriminalization or even the legal regulation of the marijuana market. In this report, I estimate the potential federal excise tax revenue that could be generated in a legally regulated marijuana market, regulated in a similar fashion to the markets for alcohol and tobacco products.

I first explore the theoretical market equilibrium effects and use standard economic theory to construct an estimation technique. I then construct estimates of the price of marijuana, the quantity of marijuana available, both from foreign sources and from domestic production, and the price elasticity of demand for marijuana. Ultimately, I find that a legally taxed and regulated marijuana market could generate upwards of $200 billion annually in excise tax revenues for the federal government.

In comparison to other federal program areas, this would be enough to fund Medicaid, or over twenty months in Iraq. This potential revenue is only one piece of the greater debate on the social costs and benefits of marijuana use. Still, my estimate has critical implications for a rational policy debate on the efficacy and efficiency of current marijuana laws.

Table of Contents

Section 1: Introduction

On January 20, 2009, President Barack Obama was sworn in as the forty-fourth President of the United States. The ramifications of such an historic moment are still unfolding from day to day, but perhaps one of the most fundamental changes that President Obama has brought with him to Washington is the intention to include and involve the American people in government once again:

> The question we ask today is not whether our government is too big or too small, but whether it works—whether it helps families find jobs at a decent wage, care they can afford, a retirement that is dignified. Where the answer is yes, we intend to move forward. Where the answer is no, programs will end. And those of us who manage the public's dollars will be held to account - to spend wisely, reform bad habits, and do our business in the light of day - because only then can we restore the vital trust between a people and their government.[1]

Over the past year or so, the state of the national economy has deteriorated significantly, with a lot of the recession being strongly felt in the past few months. Job losses, for instance, have accelerated recently. An early March 2009 article reported on job losses this February, stating that some 651,000 jobs were lost in that month alone. "Since the recession began, the economy has eliminated roughly 4.4 million jobs, with more than half of those positions—some 2.6 million—disappearing in the last four months alone."[2]

The national deficit and debt are also worrisome indicators of the current state of the economy. President Obama is working to push his Fiscal Year 2010 budget proposal through Congress, which, according to the Office of Management and Budget sets the 2009 deficit at an astonishing $1.5 trillion, or 10.6% of GDP, falling to $734 billion, or 4.2% of GDP in 2013 before starting to rise again slowly.[3] The Congressional Budget Office analysis suggests that the 2009 deficit will be even larger at $1.8 trillion, or 13.1% of GDP.[4] The CBO further predicts that U.S. national debt will increase from "57 percent of GDP in 2009 to 82% of GDP in 2019."

In response to a recession more severe than any other in over half of a century, it is no surprise that policy makers at all levels of government have worked as quickly as possible to pass various economic stimulus measures. At the federal level in particular, these measures have been extremely costly, aiming at alleviating the credit crisis, stabilizing the housing market, and investing in projects that will lead to job creation and economic growth.

A recent article in the New York Times reported on a number of state-level policy options that lawmakers are considering, including taxing pornography, brothels, and marijuana.[5] Virginia Senator Jim Webb recently introduced a federal bill that would create a commission to study the issue of mass incarceration, searching for policy options that would "refocus our incarceration policies [and] work toward properly reducing the incarceration rate in fair, cost-effective ways."[6]

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[1] Transcript—Barack Obama's Inaugural Address, New York Times
[2] Goodman, Peter and Jack Healy, "Job Losses Hint…" *New York Times,* March 7, 2009
[3] President Obama's FY 2010 Budget, Table S-1
[4] Congressional Budget Office – A Preliminary Analysis, 2
[5] McKinley, Jesse "Struggling States" *New York Times,* February 28, 2009
[6] Senator Jim Webb, Floor Statement, National Criminal Justice Commission Act of 2009

And in the coming months, as the federal and state governments attempt to fund further economic stimulus measures, policy makers will necessarily continue to consider changes in policy that can generate government revenue, catalyze economic activity and growth, and aid in balancing the increasingly bleak local, state and federal budgets.

As recent events and public dialogue have indicated, one such policy area in which there is significant potential to catalyze economic growth and reduce government waste is drug policy. A long-time taboo topic among politicians, dialogue on the subject, and particularly with regard to marijuana, has become very prominent in the media in recent weeks. In President Obama's recent online town hall, he even addressed the topic because it had been voted on highly by the online audience:

> "I have to say that there was one question that was voted on that ranked fairly high, and that was whether legalizing marijuana would improve the economy and job creation," Obama said off-handedly at the town hall. "I don't know what that says about the online audience, [but] the answer is no, I do not think that is a good strategy to grow our economy," Obama said to laughter from the town hall participants.[7]

The way he handled this question has come under fire, though, as he did not even address the question in a remotely serious manner. He took it as an opportunity to make a nice joke, engaging his live audience, but did not address the substantive question of whether the legalization of marijuana could assist in catalyzing economic growth and job creation.

This issue was brought up again in a press conference with White House Press Secretary Robert Gibbs when a reporter asked Gibbs if the President's response was a political response or an economic response, and why the President was so dismissive of a topic that is clearly important to many people, and in particular the online audience. Gibbs' responded:

> Uh, he, he does not think that, uh… that that is uh, uh… he opposes it, he doesn't think that that's the, the right plan for America.[8]

President Obama might be correct. The legalization and regulation of marijuana might not have very significant effects on the budget, job creation, federal revenues and so on. But if we are to truly "spend wisely [and] reform bad habits," as President Obama suggested in his Inaugural Address, it is crucial that we take the question seriously. It is critical, for the sake of a rational, tempered policy discussion that we attempt to understand and analyze the economic and other implications of our current drug policies, and specifically marijuana policy. While there will inevitably be non-economic objections to changing current policy, the economic analysis is particularly pertinent to the current macro-economic and political climate.

In this report, I set out to answer one question. How much tax revenue could the federal government generate in a legally taxed and regulated marijuana market? Clearly this is only a narrow subset of the economic questions pertaining to drug policy reform, and marijuana policy reform specifically. Such policy changes have potentially very wide-ranging effects that will be highly dependent on how policies change, the conditions in the current market, and cultural

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[7] Mooney, Alexander, "Obama: Marijuana Not a Good Strategy", March 26, 2009, CNN Political Ticker
[8] Guither, Pete "Gibbs Response," *Salon.com*, *Drug War Rant*, March 29, 2009

attitudes towards drugs and drug use. Because of the various limitations to any economic analysis of this sort, however, it is necessary to keep a narrow focus.

Previous economic literature has attempted to answer some of these questions. Specifically, economists have analyzed the cost savings from repealing prohibition of marijuana, and some have attempted to estimate a base level of taxes that would be generated with a change in policy. This study attempts to improve on those estimates by using existing data, however limited, to create a broader framework for understanding the projected federal revenue stream from a legally regulated marijuana market. The question of how much revenue could be generated is complex. An estimation of this nature requires not only a detailed analysis of the options for regulatory reform and the current market equilibrium—supply, demand, price, quantity, and so on—but also requires knowledge of the interaction between these variables. The nature of the question, then, naturally makes much of this analysis hypothetical and speculative.

Regardless, I intend to show, utilizing best available data and standard estimation techniques, that the legal taxation and regulation of marijuana at the federal level could generate revenue in excess of $200 billion dollars annually. While my analysis is limited, it is grounded in rational, conservative estimation techniques and parameters. The rest of this report is organized as follows.

In the rest of this section, I explore the historic context of marijuana reform, as well as the domestic and international political contexts for reform, and I briefly discuss other literature in this field. In section 2 I lay out theoretical predictions for the transition to a legally regulated market and my estimation methodology. In section 3, I discuss in greater detail the hypothetical options for regulatory reform and taxation, and discuss the specific regulatory effects that I am estimating, namely, a legally taxed and regulated market with similar features to that for alcohol or tobacco. In sections 4 and 5, I estimate an average price of marijuana, and the average quantity of marijuana on the market, respectively. In section 5 I also discuss the price elasticity of demand for marijuana. In section 6, I present my final estimates of tax revenue. In section 7, I discuss various related effects that are outside the scope of my estimates, and in section 8 I conclude.

Historical Context of Marijuana Policy Reform

The use of marijuana, the dried flower of cannabis sativa, has a long and varied history, and only in the last half-century or so has it come to be known, ubiquitously, as an illegal drug. Starting with the United Nations Single Convention in 1961, cannabis in any form has been part of the international agreements governing drug policy. Some sources suggest that the inclusion of cannabis in the international drug conventions dates back to 1925.[9] Regardless of exactly when they began, these agreements are complex and have changed significantly over the past fifty years. Essentially, "all nations prohibit both the production and use of cannabis and have been committed to do so at least since the 1961 Single Convention on Drugs."[10] Even the most liberal regimes, such as that found in the Netherlands, can best be characterized as a de facto legalization, as they formally maintain the illegality of cannabis, and its most popular form,

[9] McDonald et al., "Social Impacts of the Legislative Options…" Australian Institute of Criminology, 1995.
[10] Room et al., Global Cannabis Commission Report, 13

marijuana. While many nations have undertaken changes in or reforms of the way in which cannabis is controlled, Room is quick to remind that:

> It should be noted that departures from the international prohibition regime, at least *de jure*, have primarily concerned the individual cannabis user. The main aim of the various regimes has been to lessen the burden of criminality on possession and use, and in some places on cultivation for one's own use. Even in the most far-reaching [reform] regimes, there is no explicit legalization of production or distribution of cannabis products, which would involve numerous provisions of the international conventions besides those on use and possession.[11]

Since at least the 1970s, there has been a growing concern in the United States as to the efficacy of cannabis prohibition. During the 1970s, 11 U.S. states reduced the penalties for possession of marijuana.[12] Chronologically, these were Oregon, Colorado, Alaska, Ohio, California, Maine, Minnesota, Mississippi, New York, North Carolina and Nebraska.[13] In studies on the impact of these policies, these states have often been grouped together. Yet the wide variation in policy that continued to exist between these states has led some authors to conclude that these states "do not appear to be homogenous in significant ways that enable them to be differentiable from non-decriminalized states, at least from a statutory basis."[14] Since the late 1990s, various states that are not considered 'decriminalized,' moreover, have reduced penalties for first-time marijuana possession offenses as well. This variation between states also exists between nations, regardless of the fact that nearly all nations are party to the U.N. Conventions. This variation and non-uniform terminology makes policy analysis in the current market empirically challenging.

Room discusses the current prohibition regimes in broadly defined categories, developed initially by McDonald in 1994 for use in Australia.[15][16] Understanding the initial legal status will be critical to understanding any effects of changes in those policies, on any level of government. While the popular debate on marijuana policy has traditionally differentiated between decriminalization and legalization, this crude distinction tends to minimize the importance of incremental policy differences that can have a very significant impact on the budgetary impact of a change in policy. McDonald suggests, "The terms 'decriminalisation' (sic) and 'legalisation' (sic)… have quite different meanings for different authorities." Combining the Room and McDonald categorization of marijuana reform policies, the full spectrum of potential control regimes should include: full prohibition, prohibition with cautioning or diversion, prohibition with civil penalties, partial prohibition, medical marijuana control, government regulation and free availability in the form of unregulated markets.

Figure 1 visualizes these options, with the most prohibitive on the left. The arrows beneath indicate the range of regimes for which the terms "decriminalization" and "legalization" can be used, and illustrate more clearly that these are not particularly concrete policy categories. This visualization does not include medical marijuana control. I discuss medical marijuana laws, and their impact on the markets in greater depth in section 3.

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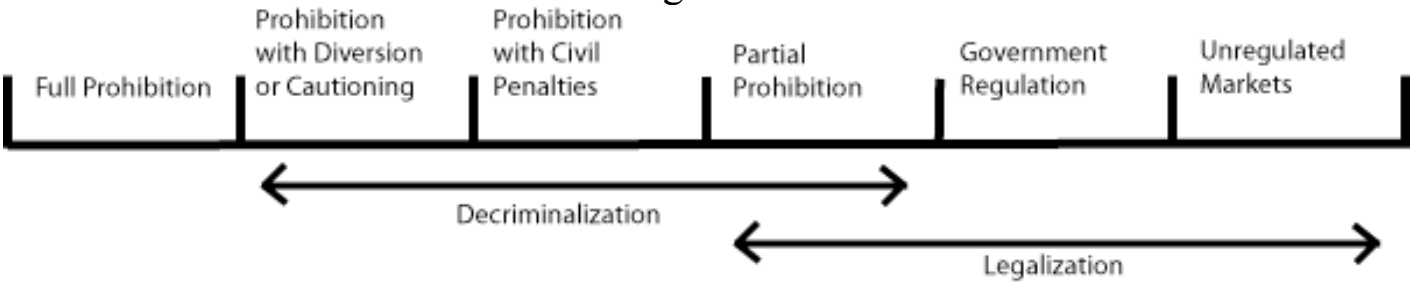
[11] Room et al., Global Cannabis Commission Report, 100
[12] Pacula et al., (2003)
[13] ibid. 4
[14] ibid. 11
[15] Room et al., Global Cannabis Commission Report, 99
[16] McDonald et al., "Social Impacts of the Legislative Options…" Australian Institute of Criminology, 1995

Figure 1



At the far left is full prohibition, which typically maintains criminal penalties for any possession offense, and is effectively the policy at the federal level in the United States. Prohibition with diversion or cautioning is slightly different in that intermediate measures can and are applied to offenders at various stages. Diversion usually refers to the redirecting of offenders into treatment or education programs, either before a trial has occurred, or in lieu of other sentencing measures. Cautioning occurs when law enforcement officials handle a situation in which an arrest could be made by giving a mere warning, or caution. It is important to note, with cautioning, that this can occur *de jure*, or in the actual laws of a given jurisdiction, or *de facto*, being implemented at the level of enforcement even though the law suggests that such an offender should be arrested. Taken together, cautioning and diversion schemes can be referred to as de-penalization, because they serve to change only the penalties for violation of the criminal law, and not the underlying legal status.

Prohibition with civil penalties is closer to what is commonly thought of as decriminalization. As opposed to criminal penalties, civil penalty regimes treat marijuana use and small possession with administrative sanctions, citations or fines. In other words, possession of small amounts of marijuana becomes effectively no different than receiving a speeding ticket. Some states already "have these offenses categorized as a 'civil violation' or a 'petty offense.'"[17] Most notably and recently, Massachusetts' voters just passed a referendum that changes law such that possession of up to an ounce of marijuana is only punishable by a $100 fine. While there was broad support for the passage of question 2, however, many local jurisdictions are now setting fines greater than the referenda implemented, and the final status in Massachusetts is far from settled.[18][19][20][21][22]

Partial prohibition can also come as both *de facto* and *de jure* legalization of possession of small amounts of marijuana. Importantly, as I have already mentioned, this does not apply to the production or cultivation of marijuana. Room discusses the important distinction between *de facto* and *de jure* legalization:

> In the [*de facto*] model, cannabis use is usually prohibited by criminal law, yet formalized

[17] Room et al., Global Cannabis Commission Report, 106
[18] Aicardi, Richard "$300 Fine for Public Pot Smoking…" February 27, 2009
[19] Applegate, Sally "Enforcement of New Marijuana Law…" February 27, 2009
[20] Mortimer, Scott "Take Notice…" March 12, 2009
[21] Stafford, Scott "Towns Weigh Ban on Pot Use" March 7, 2009
[22] Turner, Maureen. "Round Two for Question 2…" March 17, 2009

> procedures of enforcement practice (i.e., either at the law enforcement or prosecution level) have created a situation in which personal cannabis use is reliably and predictably not sanctioned by any punitive interventions. In the [*de jure*] model, the legality of personal cannabis use is defined by the letter of the respective law… Importantly, *de jure* legalization of cannabis use is not dependent on the way the law is applied in practice. [23]

The most prominent example of *de facto* legalization can be found in the Netherlands. While possession is technically illegal, the Dutch have an "expediency principle" in place, which allows law enforcement to decide whether enforcing the law against a particular action is in the public interest.[24] The Netherlands is popularly thought of as a country in which marijuana is legal due to the popularity of coffee shops, particularly in Amsterdam, in which the Dutch and thriving tourist industry can purchase small quantities of a large variety of strains of marijuana. Over the past few years, however, there has been a growing concern in the Netherlands about the "backdoor problem" of Dutch cannabis policy, in which wholesale supply networks have been established in a grey market to meet the high demand, but are not legally regulated by the *de facto* legal framework, which governs the regulations for coffee shops.[25]

Government regulation and unregulated markets are the last two cannabis control regimes in the spectrum in figure 1 above. Government regulation can also be termed legalization, but unlike allowing marijuana to be freely available to the public in a relatively unregulated market, like the market for candy or gum, it would be more strictly regulated. This typically implies that it would be taxed at a higher level than other agricultural products, and the government would regulate a similar market structure for marijuana as it does with regards to alcohol and tobacco, at least as it pertains to advertising, age restrictions, distribution licenses, and so on.

Domestic and International Political Context

Another major challenge to conducting this research is that the range of observable policy reforms is limited. Because of the international treaties regarding drugs and the drug war, as well as the complex history of the United States' involvement in those treaties, few countries have done more than adopt relatively incremental policy reforms with regard to marijuana or any other drug. This means that there is rarely a valid treatment state or nation with which to compare a control state.

The policy speculation required, moreover, is perhaps counterintuitive to the current political status of issues of drug reform in the United States. At the time of this writing, while President Obama certainly has a vastly more "liberal" set of policy positions on the drug war than his predecessor, he has consistently stated that he does not support the federal decriminalization or legalization of marijuana. The medical marijuana movement has registered some incremental policy successes lately as well. New Mexico recently licensed the first state-regulated medical marijuana dispensary[26], for instance, and Rhode Island is also set to allow for non-profit compassion centers to distribute medicinal marijuana.[27] U.S. Attorney General Eric Holder has

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[23] Room et al., Global Cannabis Commission Report, 112
[24] Room et al., Global Cannabis Commission Report, 113
[25] Room et al., Global Cannabis Commission Report, 114
[26] Holmes, Sue "First Medical Marijuana Producer in NM Approved," March 18, 2009
[27] RIPAC Medical Marijuana in Rhode Island – Compassion Centers

made the Obama Administration policy of ending federal raids on California dispensaries,[28] and Massachusetts voters recently passed Question 2, allowing for the decriminalization of the possession of up to one ounce of marijuana.[29] California and Massachusetts legislators have even introduced bills to tax and regulate the marijuana industry this year.[30] This range of reforms, and the speed at which they are increasing in recent months are far from negligible, and they represent a culture that is churning with progressive ideas. But compared to the notion of a federal, legally regulated marijuana market, they represent relatively incremental changes.

Internationally and historically speaking, as well, the idea of a regulated market is still likely to be a long way away. While it is certainly possible for a nation to avoid the various international treaties, by changing their domestic constitutions, or by passing conflicting domestic legislation, for example,[31] were the United States to shift its marijuana policy so fundamentally, the entire international drug prohibition regime could be threatened. Room explains:

> Cannabis has lately come to play an important role in the international drug control regime at the rhetorical level. The annual statements of the UNIDC always mention the estimated share of the world population that use illegal drugs. That number is dominated by cannabis. For example, in the 2005 World Drug Report the UNODC stated that there were 200 million drug users globally; of these 160 million (80%) used cannabis. The other drugs listed… had user populations totaling only 40 million, less than 1 percent of the worlds population. Without cannabis, the totals would suggest that illegal drug use is not a global population level issue. Thus the drug helps give breadth to the drug issue globally; the same is true in many member nations.[32]

Room also suggests that the United States, in particular, would likely oppose "any of the paths forward" with regard to cannabis law reform.[33] Taken together, then, critics might claim that the sort of policy speculation that I undertake in this report is too far-fetched or idealistic for the findings of this report to be practically useful or functional. This is a valid concern, but as I will argue, there are signs that the current recession could hasten changes in the political and cultural climate with regard to this issue.

Review of the Literature

The budgetary impact of transitioning to a regulated market is the focus of this study. More specifically, I will create a broader framework for and estimate of the potential tax revenues generated. The economic literature base on issues of drug use and abuse, the social and health costs of drug use, the harms to health from marijuana, drug use treatment indicators, the relationship between drugs and the criminal justice system, and so on, is obviously very extensive. A full review of all the pertinent literature is unnecessary for this study. That said, I do address briefly many of these sub-categories of literature throughout this report, as called for by the context of the various chapters. It will be helpful, however, before explaining my methodology, to understand the context of the current academic literature on this specific topic.

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[28] Meyer, Josh and Scott Glover. "U.S. won't prosecute medical pot sales," 3/19/2009

[29] Sharples, Tiffany "Ballot Initiatives: No to Gay Marriage, Anti-Abortion Measures", *Time Magazine*, November 5, 2008

[30] CA AB 390, MA Sen. No 1801

[31] For a fuller discussion of the international ramifications, see Room et al., (2008) chapter six.

[32] Room et al., Global Cannabis Commission Report, 92

[33] Room et al., Global Cannabis Commission Report, 167

For a variety of reasons, existing literature suggests that the budgetary impact of the more incremental steps would be relatively minimal in comparison to the revenues generated from taxation. There would be some savings from fewer incarcerations, as well as some savings in the judicial system if fewer offenders were sent to trial. Some small revenues could be earned from fines, but this would not generate nearly the amount that a taxed and regulated market could generate. Finally, law enforcement costs might be slightly reduced, but because law enforcement agencies at all levels of government would continue to enforce against production and supply, it seems more likely that the majority of law enforcement resources currently dedicated to the marijuana market would remain dedicated to enforcement.

With regards to a regulated market, I focus on tax revenues, and not reductions in government expenditure, or savings, because for the most part, the reductions in expenditure that would accrue from a change in policy have been more extensively studied. Miron (2005), in research funded by the Marijuana Policy Project, estimates that a regulated market would "reduce government expenditure by $5.3 billion at the state and local level and by $2.4 billion at the federal level."[34] Boyd has estimated this for Hawaii, suggesting that because of Hawaii's *"de facto* policy of lax enforcement" of marijuana laws, savings from decriminalization would only total approximately $5 million, and that legalization would save substantially more and could generate "anywhere from $4 million to $23 million depending on tax rates."[35] Austin suggests that these reports may be exaggerating the criminal justice savings, because marijuana arrests are a very small proportion of overall arrests relative to "the entire universe of arrests."[36] He admits, however, that there might be a number of hidden costs, particularly for people on parole, supervision or incarcerated because of marijuana laws.

While these potential savings from reduced law enforcement and criminal justice costs are critical to state and federal budgets, and particularly so in the current economic climate, the range of potential revenues generated through a legally taxed and regulated market have been far less extensively studied. Miron and Gettman estimate the impact of legalization on tax revenues, with Gettman being the most recent and most comprehensive estimate to date. Miron estimates $6.2 billion annually[37] if marijuana were taxed like alcohol and tobacco, while Gettman estimates some $31.1 billion annually in "lost taxes" due to prohibition.[38] Aside from Miron, Gettman, and Boyd in the case of Hawaii, there are no other recent estimates of potential tax revenues from a regulated marijuana market.

While these estimates set highly credible, conservative floors on the tax revenue that could be generated, I will attempt, in this report, to improve on these estimates in a number of ways. Essentially, this literature, while utilizing, for the most part, sound, conservative, modeling techniques, underestimates potential tax revenues. This underestimation stems from the use of a number of parameters that are too conservative, as well as the inclusion of a significant amount of data, that, on the whole, leads to underestimates of potential tax revenue.

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[34] Miron, Jeffrey A. "Budgetary Implications" (2005), 17
[35] Boyd, L. "The Budgetary Implications… for Hawaii," 17
[36] Austin, J. "Rethinking the Consequences" 13
[37] Miron, Jeffrey A. "Budgetary Implications" (2005), 17
[38] Gettman, Jon. "Lost Taxes," 2007, 35

Without the research of authors such as Gettman and Miron, undertaking an analysis of this sort would be even more of an empirical challenge. The data that exists, as I will explain, is almost always flawed, and often requires the researcher to make various assumptions, many of which are unverifiable to some degree. Ultimately, even insofar as I will be academically critical of these previous studies, this report should be seen as an attempt to improve and refine the framework under which we can estimate the effects of legally taxing and regulating marijuana and to better understand the potential tax revenue generated.

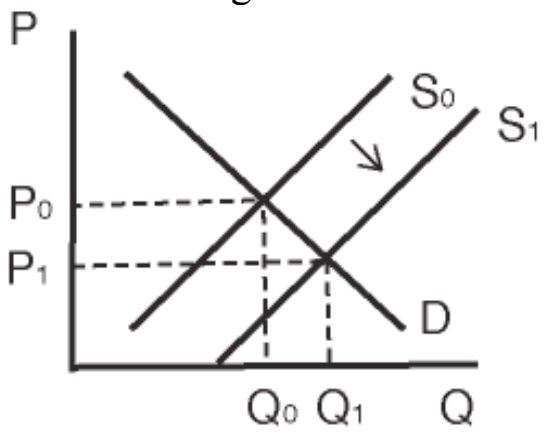
Section 2: Theoretical Predictions

Given the spectrum of policy alternatives and the complexity of the current political context, an analysis of the theoretical effects on the market equilibrium will be useful in justifying my estimation methodology. Unlike some policies, which might affect only supply or demand in a given market, the legalization, regulation and taxation of marijuana could potentially have significant effects for both supply and demand. In order to analyze these effects, then, it helps to simplify the model, and initially hold either supply or demand constant.

Shifts in Supply

On the supply side, we might first expect the change in policy to shift the supply curve outward. This effect is almost certain to occur because a significant cost to suppliers at all points in the supply chain has been eliminated, namely, risk. The cost of supplying a product to the market, regardless of quality or price, will fall considerably, causing supply to shift outward. Moreover, legalization will almost certainly cause new producers to enter the market, increasing competition and causing supply to shift outward. Figure 2 illustrates this shift outward.

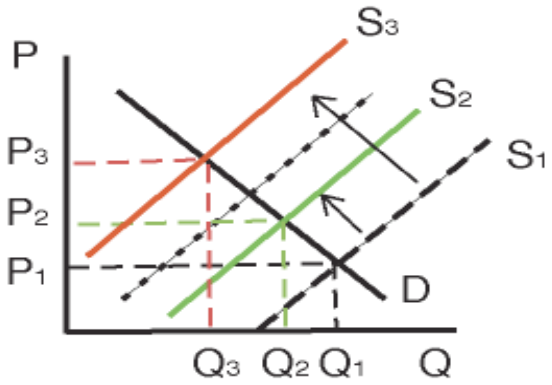
Figure 2



Very simply, the current supply, S_0 shifts outward to S_1, decreasing the price and increasing the quantity on the market. This initial shift outward in supply is certain to occur, but there are several factors that will mitigate this shift.

Producers and distributors of marijuana would suddenly be applicable to various legal market regulations, such as labor or environmental regulations. Production licenses, fees or quotas could also be applied to farms or retail distributors. Finally, there will almost certainly be an excise tax. These factors can be seen as creating a second, inward shift in supply. This second shift in supply can be seen in Figure 3.

Figure 3



This inward shift in supply that results from the costs of operating in a legally regulated and taxed market would most likely be similar to the shift from S_1 to S_2, resulting in a net shift outward in supply from the current, illicit market, but a shift inward from an unregulated market.

Hypothetically, though, it is possible that this second shift in supply would actually result in a net shift of supply inward, as such as that from S_1 to S_3 in Figure 3. This would occur if all of the costs of operating in a legally taxed and regulated market were in fact a larger costs to producers than the risks and costs that result from the illicit nature of the market. While hypothetically possible, it would most likely need to be a goal of policymakers to try to prevent this from happening.

The basic intuition here is that, as with nearly any change in policy, marijuana taxation and regulation will require a change in individuals' incentives in order to be effective. If suppliers' costs increase because of the regulations and taxes in the legal market, they may not have any incentive to comply with market regulations. Similarly, if the price that consumers face, P_3 is greater than P_0, then consumers would presumably continue to purchase the lower priced, illicitly distributed product. Becker, Grossman and Murphy suggest that compliance might still occur if enforcement of the regulations were optimal.[1] This would allow the shift from S_1 to S_3 to occur, reducing the overall quantity consumed to below present levels. I discuss incentives for compliance in greater depth in the next section 3 below. Suffice to say, however, that I assume that price will have to fall, on net, for regulation and taxation to be successful, but taxes could keep the equilibrium price and quantity roughly similar to its current level.

Elasticity of Supply

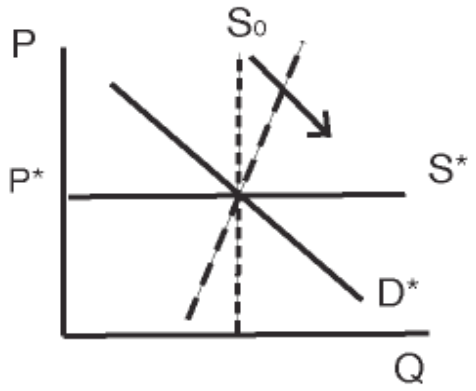
In addition to considering whether supply will shift with the change in policy, it is important to consider the elasticity of supply, and the time-horizon over which it will change. In the very short run, the supply of marijuana in the market is fixed. Farmers have planted a fixed number of crops, and while there may be some variance in crop yield from season to season, or harvest to harvest, until the next harvest the amount of marijuana that they can bring to the market is

[1] Becker et al., "The Economic Theory of Illegal Goods," 2004, p 2

independent of the price. In other words, the supply of marijuana is inelastic in the short-run. But over a longer time frame, the market for marijuana is not unlike any agricultural market in that it is far more elastic in the long run.

There are a number of reasons to believe, moreover, that the supply in a marijuana market will not only shift but also become far more elastic, and perhaps perfectly elastic, under the shift to a legally regulated market. Unlike some agricultural commodities that require certain types of land and sunlight to thrive (such as sun, or coffee), due to its history as an illicit substance, the marijuana industry has created means to grow marijuana almost anywhere. Technologies have been developed to cultivate marijuana under vastly divergent climatic conditions, indoor and outdoors, in soil and utilizing hydroponic technologies, and so on. When critical inputs to the market, such as labor, capital to invest in hydroponic growing technologies and land—both indoor and outdoor—become available and become significantly less expensive because there is less risk attached to them, the elasticity of supply will increase substantially, moving in the direction of perfect elasticity. Figure 4 illustrates the transition from the short-run, inelastic supply curve to the long run, highly elastic supply curve (in this case, perfectly elastic.)

Figure 4



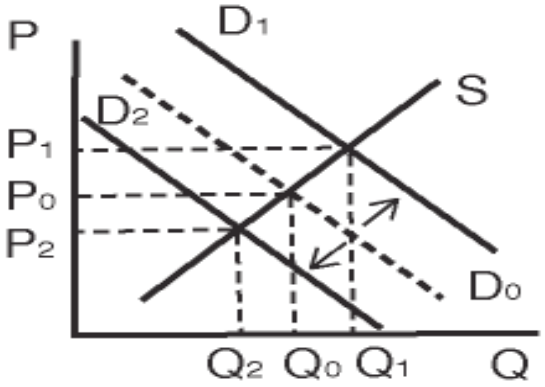
Shifts in Demand

The demand side of the market equilibrium, which until now we have assumed is constant, could also be affected by the regulation and taxation of marijuana. The first instinct is to expect that demand would shift outward. There are a number of mechanisms by which this could happen. If the change in policy suddenly changes societal and cultural attitudes towards consumption of marijuana, this could cause an outward shift in demand. Similarly, if the legalization and regulation is accompanied by an increase in doctors prescribing the use of marijuana for medical purposes, this could also shift demand outward. Supply could also shift out if a significant number of people choose not to use marijuana solely because of its illegal status.

It is important to remember that this shift in a demand is an effect that could occur *regardless* of what happens to price or supply. Unlike a shift along the supply curve, under which a greater *quantity* of marijuana is demanded in aggregate, a shift outward in demand would occur *for any price level*.

Conversely, there are a number of reasons, to think that the change in policy might not result in a significant outward shift in demand, but in an inward shift in demand. If, for example, there exists a significant "forbidden fruit" effect, whereby many consumers get some utility from the illegal status of marijuana, some fraction of consumption could fall or cease completely regardless of price, causing an inward shift in demand. In Figure 5, D_1 and D_2 represent the outward and inward shifts in demand, respectively.

Figure 5



Notice that an outward shift in demand would cause a higher quantity *and* a higher price, in the equilibrium. The opposite would apply for an inward shift, holding supply constant. I discuss these shifts in demand at greater length below.

Elasticity of Demand

The price elasticity of demand, like that of supply, is also an important factor in estimating potential tax revenues from a regulated market. In other words, how responsive to price is consumers' behavior with regard to marijuana? If supply shifts significantly, and demand is relatively inelastic, quantity consumed will only increase slightly. But if demand is elastic the quantity consumed could increase significantly as supply shifts outward under a regulated market.

Fundamental Theoretical Assumptions

From this preliminary discussion on supply and demand, it should be clear that the anticipated effects of a change in policy of this magnitude are complex, and depend greatly on what happens with supply and demand. With the potential for both supply and demand to shift, and to shift substantially, as well as the potential for price-elasticities of the two to change, it is helpful to clarify a few fundamental theoretical assumptions.

Perfectly Elastic Supply

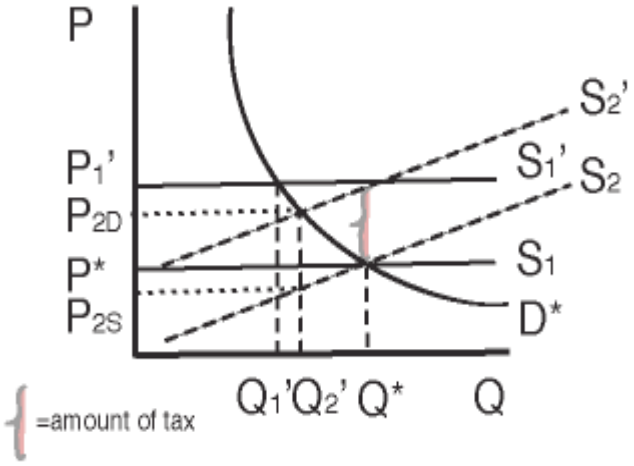
First, I assume that the long-run price elasticity of supply is perfectly elastic. In a perfectly competitive market, this could very well be the case. It is a stronger assumption in this case, however, because the regulatory framework is likely to make it difficult to obtain certain inputs

to licit production, such as the proper licenses, and to attempt to put a cap on large-scale distribution and cultivation. Some of these costs and inputs into production can be passed off to consumers in the form of higher prices, but some will likely effect producers' surplus.

This assumption is necessary for estimating the tax revenue in large part because of the imprecise nature of the data on price and quantity. The incidence of any tax is determined by the elasticity of supply and demand. In a situation where supply is perfectly elastic, consumers bear the full burden, and when supply is perfectly inelastic, producers bear the full burden of any tax. When neither supply nor demand is perfectly elastic nor inelastic, both consumers and producers will bear some of the tax incidence.

Accordingly, to estimate the new equilibrium quantity demanded, we not only need to know the tax level, but we need to know what the resulting price faced by consumers will be in the resulting market equilibrium. If the supply curve in a regulated market is horizontal—if its supply is perfectly elastic in the long-run—equilibrium price is equal to the marginal cost of production, and the price consumers pay increases by the full amount of the tax, regardless of the type of tax imposed and who is legally responsible for paying the tax. Figure 6 illustrates this more clearly.

Figure 6



In the perfectly elastic situation, represented by S_1 and S_1', the curve shifts by the full amount of the tax. The initial equilibrium price, P*, increases to P_1', the price faced by consumers, and producers continue to receive P*. In the case where long-run supply is highly elastic, but not perfectly elastic, however, the curve shits by the full amount of the tax (in the case of a unit tax), but since producers do bear some of the tax burden, the price received by producers falls from P* to P_{2S}, and the price that consumers pay is P_{2D}.

There are a number of important effects of this assumption. First is that since supply is perfectly elastic in the long, there is no difference between applying an ad-valorem tax and a unit tax. An ad-valorem tax typically causes the curve to swivel rather than shift in a parallel fashion, but in our situation, the difference between the two will be a matter of how much the curve shifts, in

other words, how much the price faced by consumers increases.

A second major effect of this assumption, though, is that any given tax level will reduce quantity demanded more than it would if supply were elastic but not perfectly so. This can be seen in Figure 5 simply in that Q_1' is less than Q_2'. This has a significant effect on the resulting estimates of tax revenue, because a unit tax of $1.00/g, for example, will cause fewer grams to be consumed if supply is perfectly elastic then it does if supply is highly, but not perfectly, elastic. Ultimately, then, the estimates of the revenue that would result from a given tax level are likely to be understated by this assumption.

Constant Elasticity of Demand

As you can see in the non-linear demand curve in Figure 5, my model will utilize a constant elasticity of demand. I discuss the reasons for this further in section 5, but this is also ultimately due to limitations to data, and particularly limitations in the data about the characteristics of consumption (i.e., frequency of use or quantity of marijuana per use) for marijuana users.

No Long-Run Shift in Demand

Perhaps the most controversial theoretical assumption I will make in my estimates of tax revenue is that demand will not shift in the long run. As I mentioned previously and illustrated in Figure 5, there is some question as to whether demand would shift outward or inward, if it shifts at all, and this is certain to vary between the short-run and the long run.

I will not consider the potential for a long-run inward shift in demand to result from the change in policy. This would imply that there is such a large forbidden fruit effect that prohibition induces consumption. Aside from the fact that there is very little evidence for this, if this were thought to be the case, one of the principal arguments for prohibition would be moot.

The potential for a long run, outward shift in demand is certainly more troublesome. A shift in supply that reduces price would already cause an increased quantity demanded, and any adverse consequences of this would only be exacerbated by a long-run outward shift in demand. This distinction between increased quantity consumed in aggregate and a long-run shift in aggregate demand is extremely important here.

A shift in aggregate demand would cause higher demand for marijuana regardless of price. At the consumer level, then, the assumption that demand does not shift does not mean that new users won't enter the market. If a consumer who currently does not use marijuana decides to do so because the price falls, this is a shift *along* the demand curve. For the demand curve to shift outward in aggregate, something has to catalyze increased consumption regardless of price.

The literature base and the available evidence support the assumption that demand would not shift in the long run, to some extent at least. First and foremost, Miron makes this assumption as well in his 2005 report.[2]

[2] Miron, Jeffrey A. "Budgetary Implications" (2005), 12

Data show that the legal risks from marijuana use and possession in the United States are low. There are more than 1.2 million drug possession arrests each year for all drugs, but there are more than 28 million users, making the probability of arrest for purchase or possession low. Furthermore, many of these arrests occur for some other violation of the law, such as speeding or loitering, and it follows that otherwise law-abiding citizens face a low risk of arrest.[3] A lot of the consumers who would participate in a regulated market, then, are likely to be already participating in the illicit market because demand-side risk is trivial for so many people.

In addition to a low risk for retail consumers, marijuana is highly available. By many accounts it is the most widely available drug in the United States. Hudson puts it quite simply the Marijuana Availability report for the Federal Research Division, that "marijuana is the most readily available and widely used… drug in the nation. Its prevalence has contributed to both an acceptance of marijuana use among some adults and adolescents and a perception that the drug is not harmful."[4] As my data in section 5 will show further, the estimated quantity of marijuana available in the market is easily over 14,000 metric tons.

Essentially, then, the argument that demand would not shift can be summarized by the fact that the risk for consumers is currently so low, the product is so highly available, and the impact of decriminalization, where it has been studied, is still somewhat inconclusive, it is not inconceivable that were the United States to tax and regulated marijuana, the long-run demand curve would not shift. Consumers who would participate in a licit, regulated market are already consuming an optimal amount of marijuana, given the price that they face in the illicit market.

If all consumers currently factor these risks into their reservation price, then the entire potential market is adequately captured in the current, illicit demand curve. Admittedly, there are reasons to believe that this is an over-simplification.

Many employers drug-test their employees. Some consumers face greater risks and costs then others in obtaining marijuana, depending on their age, location or race. Consumers perceive health risks, social stigmas and any number of other factors differently, and all of these are likely factored into their participation decision, but are not necessarily dependent on the observations of price that I use in this report.

It seems more likely, then, that some of these things are non-price considerations and could be affected by a change in policy. If this were the case, it would imply that demand would shift out, at least in the short-run. Effects on the long run are not as clear. The role of varying cultural attitudes and patterns of behavior is particularly important here. Cultural attitudes with regard to marijuana are dynamic. They change in response to scientific discoveries and research, current events and between generations.

There is a modest body of literature that attempts to estimate the effect of reduced penalties and other marijuana reforms on prevalence and use. Pacula, Chriqui and King suggest, "The policy of decriminalization appears to mean something" with regard to prevalence among youth, but

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[3] Miron, Jeffrey A. *Drug War Crimes*, 2004
[4] Hudson, Marijuana Availability, 1

that "formal decriminalization statutes may be an indicator of a larger social acceptance of marijuana use within the state… [Or] an indicator of greater public knowledge… of the reduced penalties,"[5] rather then causally effecting rates of use. MacCoun and Reuter discuss the effect of different regimes as well:

> The Dutch experience, together with those of a few other countries with more modest policy changes, provides a moderately good empirical case that removal of criminal prohibitions on cannabis possession (decriminalization) will not increase the prevalence of marijuana or any other illicit drug… Making cannabis fully legal is likely to increase its use substantially because of promotion, particularly in the USA with its peculiar dedication to commercial free speech"

Room discusses some of the challenges of this literature, specifically the issues of time inconsistent reactions to changes in policy, and the endogenous nature of policy reform and higher rates of use. Still, Room notes that:

> There is a consensus that depenalisation (sic) in the Netherlands did not, in itself, lead to increases in population levels of cannabis use among adults nor among young people. This finding is consistent with results in … Australia and the USA. Secondly, the Dutch system does appear to have successfully separated the market for cannabis from other substances. The majority of cannabis users who buy their cannabis from the regulated environment of coffee shops do not need to have contact with other illicit sources… where they may be exposed to other drug use and criminality. Thirdly, there are competing views of the impact of the 'commercialization' of cannabis sales from the mid-1980s to mid-1990s. On the one hand, the increases in prevalence of cannabis use among youth appear to mirror changes in other countries that begin prior to this period. On the other hand, the prevalence changes correlate with changes in policy, increasing as access and availability increased.[6]

I deal with issues of promotion, advertising and commercialization in the following section on tax and regulatory options and structures, but the potential for "larger social acceptance" in decriminalized states or jurisdictions of any sort is a serious confounding factor in attempting to determine if changes in policy could be causally related to increased use. In liberal democracies, cultural values, attitudes and behaviors towards marijuana are supposed to reflect popular sentiment. There is a robust economics literature dedicated to median voter theorem and other means of understanding how policy is formed in a democracy. If "decriminalization" and other marijuana policy reforms were not correlated with greater use, it would be counterintuitive. Jurisdictions with greater numbers of users and people who view the drug in a less negative social light are likely to be the first to enact reforms.

Statistician Nate Silver recently argued that given the current trajectory of public opinion with regard to marijuana legalization, it would not be until 2022 that there would be serious debate about legalizing marijuana at the federal level.[7] Moreover, cultural attitudes would likely continue to change after any change in policy. If we expect the kind of effects that could shift demand to exhibit themselves dynamically over time, and to catalyze the policy change, as opposed to the policy change catalyzing a shift in demand, it is not unreasonable at all to assume that there would be no shift in demand caused by the change in policy.

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[5] Pacula, Chriqui and King, 26
[6] Room et al., Global Cannabis Commission Report, 144-145
[7] Silver, Nate, "Americans Growing Kinder to Bud", 2/22/2009

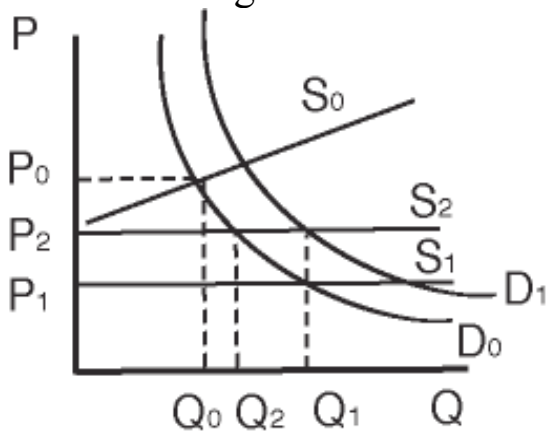
I have stated so far that I assume that there will not be an outward shift in demand in the long-term, even as I recognize the inherent flaws of this assumption given the fact that there could easily be a short-term shift, and that cultural attitudes and behavior towards marijuana use are dynamic and would be expected to be changing preceding and following a change in policy. Why, then, do I assume that there would no shift in demand, in absolute terms?

If coupled with the assumption that there would be perfectly elastic supply, it might seem that it is not necessary to assume no shift in demand because with perfectly elastic supply, there is no potential for a net shift in demand, resulting in the equilibrium of Q_1 and P_1 from Figure 4. To address this, I digress and explore the possibilities if demand is allowed to shift.

Allowing Demand to Shift

If we temporarily allow demand to shift, in the short run price could increase before the supply side reacts to the change in policy. This could be detrimental to initial enforcement, as per my discussion of incentives in the next chapter, because it would delay the incentives of both consumers and producers to change their current acquisition behavior. In the long run, however, critics might still object that a slight shift outward in demand should not alter my estimation methodology if supply is perfectly elastic. To some extent, this is true, but once again, the limitations of the data available for this type of analysis require that demand not shift in the long run, as it does in figure 6.

Figure 7



Without a shift in demand, the taxed and regulated quantity and price will be P_2 and Q_2. With a shift in demand, the regulated equilibrium quantity shifts to Q_2, but it is unclear how large this shift would be in the long run, if it happens at all. Given that my estimates of P_0, P_1, Q_0 and the elasticity of demand that follow are already inherently imprecise to some degree because of the data, attempting to account for a shift in demand of some unknown magnitude would only serve to inflate my estimates. The estimation methodology that follows rests on this assumption, as well as the two other aforementioned fundamental assumptions.

As I have already intimated, this final assumption that demand will not shift is a controversial assumption because it implies that the associated externalities of increased consumption will be more negligible then they would if I accounted for a potential shift in demand. In no way should the application of this assumption be taken to imply that these externalities are not or should not be a concern with regard to rational public policy, and I address related budgetary effects, including the impact of this policy change on health, in some greater depth in section 7.

However, economic theory suggests increased consumption of a good, per se, even an addicting good, is only negative insofar as its price does not reflect the full social costs of that good. If the price that consumers pay reflects the externalities generated from a potentially harmful good, through taxes, for example, then individuals' maximization of private utility will still be socially optimal.

And, ultimately, I have shown that these assumptions only serve to bias my final estimates of tax revenue downward. With perfectly elastic supply, this is because quantity consumed will fall by a greater amount with the application of a given tax, τ, than it would if supply were highly elastic, but not perfectly so. Clearly the assumption that there would be no shift in demand also biases the resulting estimates downward because a smaller aggregate quantity is consumed. Miron notes this downward bias of the assumption that demand will not shift as well.[8]

Methodological Overview

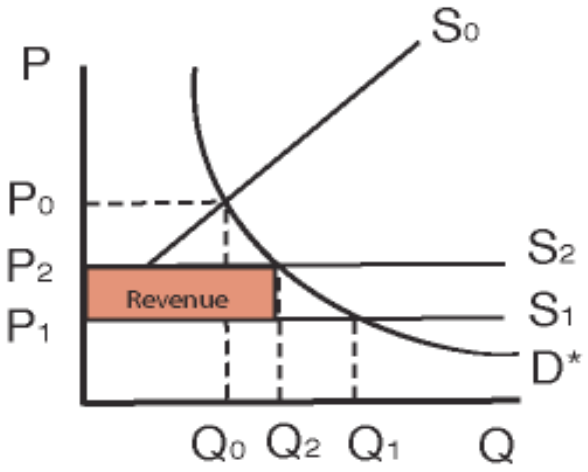
The preceding discussion of the theoretical effects of regulating and taxing marijuana guides my overarching estimation methodology. While I will discuss my estimates of the specific variables in greater depth in the following chapters, my estimation technique, quite simply, is to estimate a standard equation for tax revenue:

$$(1)\ R=\tau * Q_2$$

Here, τ is the tax rate, P is the price of the good and Q is the quantity consumed. Remember, though, that we want to estimate this equation not for the current illicit market, which is challenging enough, but for a hypothetical regulated market. Since we are interested not in the current market, per se, but in the way in which the market would change under a system of legal regulation, it helps to split this equation by the various shifts in supply that will occur with the change in policy.

[8] Miron, Jeffrey A. "Budgetary Implications" (2005), 12

Figure 8



In the current illicit market, supply and demand are in equilibrium. The market price, P_0 and quantity, Q_0 are determined by the intersection of supply and demand, as in Figure 7. In the transition to a regulated market, supply becomes more elastic and reaches some "unregulated state," illustrated by S_1. In this state, P_1 is the marginal cost of production, and quantity demanded is Q_1. The most important variable for our analysis of this equilibrium is P_1, because P_2 is defined as $P_1+\tau$. Imposing a tax on this market shifts supply upward by the full amount of the tax to S_2 because of the assumption that supply is perfectly elastic.

Our variable of interest is R, revenue, from equation 1. The data available, however limited, provide the framework for my estimates of P_0, P_1, Q_0 and a constant elasticity of demand, ε_D. To solve for R, we must first solve for Q_2 from these estimated variables. Keep in mind, though, that we are estimating the shift from equilibrium P_0, Q_0 to P_2, Q_2. Equilibrium P_1, Q_1 is only of interest to us insofar as we must estimate P_1 to be able to estimate the tax rate or level.

Elasticity, by definition, measures the percentage change in quantity relative to the percentage change in price. Mathematically, this can be expressed as follows:

$$(2)\ \varepsilon_D = [(Q_2-Q_0)/Q_0] \,/\, [(P_2-P_0)/P_0]$$

In this situation, we are solving for Q_2 based on Q_0, P_0 and ε_D. To do this, we can rearrange equation 2 algebraically:

$$(3)\ [\varepsilon_D *[(P_2-P_0)/P_0]]*Q_0 + Q_0 = Q_2$$

Recall the definition of P_2, however. P_2 is simply the difference between a regulated, untaxed price and a regulated, taxed price. How we express this mathematically will differ slightly depending on whether we are estimating a unit tax or an ad-valorem tax.

With a unit tax, this can be expressed in equation 4:

$$(4)\ P_2 = P_1 + \tau$$

Or, in the case of an ad-valorem tax:

$$(5)\ P_2 = P_1\,(1+\tau)$$

Accordingly, equations 4 and 5 can be re-written solely in terms of the variables that I will estimate with the best available data in the chapters ahead:

For a unit tax:

$$(6)\ \ [\varepsilon_D * [[(P_1+\tau) - P_0\,]/P_0]] * Q_0 + Q_0 = Q_2$$

For an ad-valorem tax:

$$(7)\ \ [\varepsilon_D * [[(P_1\tau+ P_1) - P_0\,]/P_0]] * Q_0 + Q_0 = Q_2$$

This methodological framework is effectively an extension of the framework under which Gettman estimates the lost taxes due to prohibition. Gettman, however, estimates the size of the current market without attempting to apply hypothetical parameters for a regulated legal market. As I will show further in section 6, the result of this process is an estimate of potential federal excise tax revenues that are substantially larger than other current estimates, and a framework for establishing the optimal tax rate—one that generates a large amount of revenue while minimizing the change, or perhaps even reducing, quantity consumed. In turn, my estimates have critical implications for stimulating economic growth and improving welfare.

Section 3: Tax and Regulatory Options for Reform

Unlike the price and quantity of marijuana in a legally regulated market, the tax rate and the regulatory structures that would govern such a market would be created through the political process. If policy makers were undertaking a serious conversation about the regulatory status of marijuana, a number of tax structures, tariffs, producer licenses, distributor licenses and so on, would be taken into consideration at multiple levels of government. This range of options makes it challenging to estimate the tax revenues that such a market would generate, because these taxes and regulatory schemes would all factor into the pre-tax, regulated price of marijuana, serving to counterbalance the impact of any initial outward shift in supply. Yet as I have already mentioned, if the price of marijuana does not fall for consumers, there is a strong likelihood that a significant portion of the black market would remain in business.

In this section I will first describe the range of tax and regulatory options available to policy makers within the construct of a legally regulated market. I will then discuss some of the general considerations for these options and the limitations thereof, as well as some of the considerations for the incentives of consumers and producers to comply with the legal regulations. Finally, I describe the range of taxes that I estimate.

Regulatory Options for Production

A change of policy of this magnitude requires that regulations be established for all levels of the new market. Primarily, regulations, taxes and fees must be established for the domestic production, importation, and distribution of marijuana. While my analysis will focus on a legally taxed and regulated market, it is important to briefly consider two alternative regulatory options that would represent similarly significant changes in the underlying market structure: the full regulation of marijuana as a prescription drug, and allowing marijuana to be freely sold and distributed with minimal regulation—quite literally, a free market.

Medical Marijuana Regulation

The medical marijuana movement in the United States has grown rapidly over the past 10 years. As of November 2008, thirteen states had passed some sort of effective medical marijuana law, and another seventeen states had enacted a law recognizing the potential benefits of medical marijuana, but were effectively inoperable because they required federal recognition.[1] As of this writing, however, only one state has passed any legislation specifically licensing the distribution of medical marijuana, though several other states have bills pending.[2] Perhaps most notably, California allows collectives of patients to grow marijuana together under state law, and this has effectively given rise to a wide-ranging network of medical marijuana dispensaries.[3] States with medical marijuana laws that do not have any regulations or laws governing the distribution (all but one or two) allow patients to grow marijuana for personal use. In addition to the possibility that marijuana regulation is treated almost solely as a medical issue, the rapid changes taking place in the legal realm for medical marijuana pose a challenge to estimating the effects of a legally regulated market.

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[1] State-by-State Medical Marijuana Laws, MPP.org
[2] "Medical Marijuana Producer in NM Approved," 18 March 2009, Associated Press
[3] "Active State Medical Marijuana Programs – California," NORML.org

In some sense the growth in the number of dispensaries in California and the ease with which a prescription can be obtained (patients need only possess a "written or oral recommendation" that they would "benefit from medical marijuana"[4]) make the current state of marijuana in California similar to the *de facto* legalization that we observe in the Netherlands, in some ways. Some accounts even suggest that doctors may be advertising to give consultations to potential "patients", and different dispensaries (the more daring, generally, as until recently federal raids on medical dispensaries were somewhat routine) even advertise with coupons.[5]

The rapid way in which the domestic cannabis industry is already growing poses a serious challenge to estimating the effects of legally regulating the market. The marijuana industry, like others, is not static, and it is constantly responding to legal and economic incentives. Moreover, from a political standpoint, the very fact that there has been a great deal of debate and experimentation in many states with medical marijuana initiatives makes it politically more feasible for other states to follow suit. It is not inconceivable that future policy alternatives regarding the recreational use of marijuana focus on marijuana's properties as a medicine, and treat recreational use of such similarly to the recreational use of other prescribed medicines, such as Xanax or Valium.

Ultimately, however, the medicinal use of marijuana and the various policies governing such is relatively distinct, economically, politically and theoretically, from the recreational use of marijuana, and so my analysis will not consider the medical regulation of marijuana in the scope of a hypothetical regulatory framework. While the medical framework certainly has its merits, and in a broader discussion of policy alternatives should not be dismissed without thorough consideration of its costs and benefits, it is not useful for this evaluation for several reasons.

First and foremost, prescription medicines are usually not taxed. As of January 1, 2008, in forty-nine out of fifty states, prescription and non-prescription drugs were either exempt from taxes, or were taxed at the normal sales tax rate.[6] Only in Illinois are prescription and non-prescription legal drugs taxed separately, and this is a 1% ad-valorem tax. Thus, if the only policy alternatives under consideration with respect to marijuana use focus on the fact that it is a drug with legitimate medicinal purposes, the greatest budgetary impact would not be from taxes, but rather would stem from the reduced cost of enforcement of marijuana prohibition. The current regulatory framework for dealing with the recreational use of otherwise prescription drugs, however, is significantly limited where it exists at all. Consumption data reveals the recreational use of prescription opiates (pain-killers), as well as drugs for attention deficit disorder, depression and various other conditions, but this has traditionally not been a focus of law enforcement authorities.

Another, more underlying reason that the medical framework is not useful for this evaluation is that due to the already limited data governing marijuana use generally, it would be nearly impossible to attempt to differentiate between the medical market and its impact, and the recreational market. Current behavior with regard to the distinction thereof is constantly in flux.

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[4] ibid.
[5] Samuels, David "Dr. Kush," *The New Yorker*, July 28, 2008
[6] State Sales Tax Rates, TaxAdmin.org

The possibility for cross-supply and cross-consumption between the two is a very serious possibility, but there is simply not enough data to attempt to factor that into this analysis.

Other Regulatory Frameworks

The second current regulatory framework for some substances is the completely unregulated market. This is similar to the current market for caffeine products in the United States, which are only regulated by the regulations governing food and drink. Caffeine in particular has been the subject of controversy recently due to its relationship to issues of fair international trade, fair labor and environmental issues. Furthermore, an unregulated market is also the case for a small number of other psychoactive substances, such as Salvia Divinorum, an herbal hallucinogen that is only recently being added to the controlled substances list in many states.[78]

The last regulatory framework, and the framework which I will focus on for the purposes of this analysis, is that which currently governs the production and sale of alcohol and tobacco. Regulations and taxes vary widely from state to state, and often vary even at the county or city level. Regulations include excise taxes, age restrictions for purchase, age restrictions to serve alcohol, licenses or direct provision of alcohol by the government, blue laws restricting purchase to certain days of the week and restrictions on public consumption. In the broader debate on the legalization of drugs and the costs and benefits of various drug policies, the regulations governing alcohol and tobacco usage are not uncontroversial. Youth access to alcohol and tobacco is a significant public policy concern, as are related societal costs of drunk driving or second-hand smoke.

That said, for both theoretical and practical reasons, it makes sense to understand a shift in marijuana policy from its current level of nearly full prohibition, with depenalization in some states, to a regulatory framework that would be similar to the most comparable currently legal drugs.

Even if we agree that the regulatory framework governing alcohol and tobacco is the most appropriate to use in conceiving of a regulatory framework for marijuana and other cannabis products, this does not necessarily help to define the regulations that would be applied. Alcohol and tobacco regulation varies between states. Some states are the only distributor of alcohol. Some states license private business for distribution. Cigarette taxes vary widely from state to state. There is a wide range, then, of specific policies and regulations that could be enacted with regard to marijuana, and which precise policies are enacted will clearly make a significant difference in any estimate of potential tax revenue.

General Assumptions and Theory about Regulatory Policy

I have just discussed in section 2 why supply would shift outward in the move to a legally regulated market, but the regulations implemented will clearly mitigate this shift to some extent. These regulatory effects consist of two basic types of effects: monetary effects, such as taxes or licensing fees, and other restrictive market regulations, such as minimum age requirements or

[7] Sears, Ashley. "Salvia: A Legal High in Most States," Northwestern, University
[8] "SD Bans Salvia Divinorum," AP, March 4, 2009

retail purchase quantity limits. These also impose supply-side costs that will factor into the price of the good. These features would almost certainly be part of a regulated, taxed market for marijuana, but precisely how they effect price is extremely important. A critical goal of any regulatory policy enacted, however, is to ensure compliance. While price would most likely have to fall, fundamentally, this relates to the basic incentives of market participants.

Demand Side Incentives to Comply

Many consumers of marijuana would have an incentive to comply with the new regulations even if the price increased or remained the same in the new market, because many would perceive a large benefit from the reduced risk. If a product were readily available even at the same price as it is now, but carried less legal risk, this would provide an incentive to comply with the regulations in the legal market for many (if not all) participants. Specifically, about 60% of annual marijuana users do not use any other illegal drug,[9] and these users could eliminate this risk entirely by complying with the legal regulatory framework. Some users might thus be willing to pay a premium in the form of a higher price for the added utility of reduced legal liability. If all users acted in this manner, the supply side incentives to comply, which I discuss below, would become irrelevant, because if consumers do not purchase marijuana from the black market, it will cease to exist.

That being said, to ensure that the vast majority of marijuana users comply with the legal regulations and participate in the legal market, price would likely have to fall. The reason for this has to do with current patterns and behaviors relating to consumption. For the marginal consumer of marijuana, their utility function for consumption already includes whatever risk is present, and they still maximize utility at the given price. If users have already chosen to participate at a certain utility maximizing level given the price that they face, which includes a measure of the legal risk, eliminating that legal risk, in and of itself, should not effect their utility calculation significantly, except insofar as it reduces price. It follows that if the product with reduced risk associated with it costs more, there is little reason to believe that a consumer will decrease consumption from that which currently maximizes utility. Instead, he or she will simply continue to purchase from the black market at the price he or she faced before the policy change.

There are other things, aside from price, that would affect consumers' incentives to comply with the regulated market. For instance, a minimum age restriction of 18 or 21 for purchasing would tend to induce non-compliance by those under the minimum age who already participate in the market, or those who might like to consume marijuana. The demand for and use of marijuana by youth has been relatively thoroughly researched.

National Survey on Drug Use and Health (NSDUH) data suggest that marijuana is already prevalent among youth. In 2007, twelve percent of 14- and 15-year olds used marijuana, and over twenty-three percent of 16- and 17-year olds did so.[10] Still, eighty-seven percent of annual users were adults in 2007. Comparative studies of youth consumption with the Netherlands show that comparatively fewer children under the age of 15 have experimented with marijuana.[11]

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[9] Gettman, Jon. "Consistent, Persistent, Resistant," 15
[10] Gettman, Jon. "Consistent, Persistent, Resistant," v
[11] Room et al., 62

Just as with alcohol and cigarettes, it is unlikely that these regulations would completely prevent youth from experimenting with marijuana. The literature suggests that youth experimentation with the drug is price sensitive, as we would expect. If price falls and the drug becomes even more readily available, youth prevalence could increase.[12] The vast majority of youth who choose to consume marijuana in the illicit market will continue to find sources and means to do so in a regulated market. The marijuana industry is highly dependent on social sources of distribution currently,[13] and the importance of social sources in youth access to tobacco and nicotine is also well documented.[14] This could be a significant source of non-compliance with the regulations, particularly if youth continue to acquire marijuana through illegal channels, but there is no reason to suspect, all things being equal, that youth access to marijuana would not originate in the regulated market just as youth do not purchase cigarettes from drug dealers.

Similarly, consumers could be induced not to comply if there are significant quantity restrictions that prevent buying in bulk. Take, for example, an individual who personally consumes an ounce of marijuana every week, or 3.5 grams per day. It could be the case that in the regulated market, retail purchases are limited to 2 grams per day. If this consumer wanted to continue to use 3.5 grams per day, they would accordingly have to purchase from different distributors daily (if there were no regulating mechanism preventing this kind of evasion) or they would have to remain on the black market to get their utility maximizing quantity of the drug.

Homegrown Marijuana and Demand-Side Incentives

Another characteristic of the market for marijuana that complicates this further is that consumers could presumably grow marijuana for their own consumption, avoiding a retail market and any tax entirely. The data indicate that the fraction of the market that grows marijuana for personal consumption in the United States, however, will be negligible. In some countries, such as Spain, there is a seemingly non-negligible amount of marijuana consumed that is homegrown, and in the United States the social sources of marijuana are well documented.[15] But it seems highly unlikely that home cultivation, in whatever capacity it exists now, would continue in a legally regulated market.

Growing marijuana is a labor intensive process, and a considerable investment both in direct costs, such as the acquisition of necessary materials, and in indirect costs, such as the opportunity costs of the time involved in learning how to grow marijuana well would be required of any consumer who wishes to grow for personal consumption. While the risk of growing marijuana would almost certainly decrease, the direct and indirect costs of cultivation would not change considerably, and the presumable benefits from it decrease in proportion to the decrease in risk, given that a high-quality product would be easily accessible, potentially much less expensive than in the illicit market. It seems very unlikely that the rational consumer, then, would choose to grow for personal consumption.

In terms of data, however, the assumption of negligible home growing is not particularly verifiable. Aside from the fact that the NSDUH data suggests that most users receive marijuana

[12] Room et al., 144-145
[13] Room et al., 74, 116
[14] Harrison et al., (2000)
[15] Room et al., 74, 116

through social sources, and does not even report on the level of home growing, it is possible that the proportion of those who do grow for personal use is increasing. Particularly as attitudes towards personal cultivation change as states incrementally continue to reduce penalties for use, possession, and for the medicinal use of marijuana, home cultivation could become a significant means of non-compliance on the demand-side.

At present, however, it remains the fact that the fraction of the market that would choose to cultivate personally should be small enough to be negligible in the long run. If legislators and policymakers were concerned that this would hinder compliance, moreover, they could enact some sort of personal cultivation license. If the risk of personal cultivation (through a fine or jail time) without a license exceeds the cost of the license, this would presumably prevent non-compliance through personal cultivation, for reasons similar to the Becker analysis of compliance in a legal market described below. I discuss this type of license and other regulatory structures further below in this section as well.

Supply Side Incentives to Comply

Understanding the incentives that producers and distributors will face is slightly more complicated but perhaps even more important than understanding the consumers' incentives under a change in policy. Hypothetically, we can envision a situation in which such a change in policy is ineffective because it catalyzes full evasion of the system by producers. It is far more likely, however, that suppliers would have significant incentives to comply with legal market regulations, taxes and fees.

Nadelmann (1992) discusses the four potential responses of current producers to ending prohibition:

> Illicit vice entrepreneurs seem to respond to decriminalizations and shrinkages in illicit markets in any of four ways. Some succeed in making the transition to legal entrepreneurship in the same line of work. Some seek to remain in the business illegally, whether by supplying products and services in competition with the legal market or by employing criminal means to take advantage of the legal markets... The third response of bootleggers and drug dealers is to abandon their pursuits and branch out instead into other criminal activities involving both vice opportunities and other sorts of crime...The fourth response--one that has been and would be attractive to many past, current and potential drug dealers -- is to forego criminal activities altogether. Relatively few criminal pursuits can compare in terms of paying so well, requiring so few skills...[16]

While these four options are by no means exhaustive, there is reason to believe that in the case of marijuana regulation they encompass the vast majority of the current suppliers, producers and other participants in the marijuana distribution network. Of these four responses, moreover, it seems that the most detrimental response to the creation of a successful legal market is also probably the least likely to be relevant to such a policy change. That is to say, the evasion of the legal market through competing directly with it, as such, would probably occur least of these four responses because illegal producers simply would not be able to compete.

As I have already mentioned, risk contributes substantially to suppliers costs, and therefore, to price. Regulation of production in the legal market would reduce risk substantially to any

[16] Nadelmann, (1992), "Thinking Seriously," 115

producer that chose to comply. In turn, legal producers could offer marijuana at a lower price in the legal market than in an illicit market. In the short run, the marijuana that is already produced would continue to be sold illegally, but in a long-run equilibrium legal producers who do not face the risk of continuing to produce in an illegal market would force illegal producers out of the market.

Becker, Grossman and Murphy discuss the ability of a regulated market with a tax to enforce compliance:

> Assume that enforcement against drug producers who try to avoid the monetary tax by selling in the underground economy is sufficient to raise the unit costs of these producers to ...[some] P*… [and] if the monetary tax is then set as slightly less than t*=P*-c [where c is the competitive price of drugs], firms that produce in the legal sector will be slightly more profitable than illegal underground firms. The latter would be driven out of business, or become legal producers... Enforcement costs would then be lower with this monetary tax than with optimal enforcement since few would produce illegally... in equilibrium no one produces underground. The government could even enforce an optimal monetary tax that raises market price above the price with optimal enforcement when drugs are illegal. This is sometimes denied with the argument that producers would go underground if monetary taxes are too high. But the logic of the analysis above on deterring underground production shows that this claim is not correct. Whatever the level of the optimal monetary tax, it could be enforced by raising punishment and apprehension sufficiently to make the net price to producers in the illegal sector below the legal price with the optimal monetary tax.[17]

Here, Becker shows fairly conclusively that taxation can better enforce the socially optimal consumption of a good than can prohibition, but this relies on assumptions about the effectiveness of enforcement, and assumptions about the way that producers internalize risk. In the case of taxing and regulating marijuana, it might be the case that for any number of reasons, de jure or de facto enforcement against underground firms would not be less than Becker's t*=P*-c. In other words, it might be the case that even if producers internalize the risks involved in continuing underground production, as we expect them to do, *de facto* enforcement could be ineffective enough that underground firms are still profitable. In this case, the equilibrium could still include some degree of evasion by producers.

Current enforcement against marijuana and other drugs, and the widespread availability of marijuana, seem to indicate that even for suppliers, risk is currently low. If drug enforcement authorities enforcing current laws with regard to other illicit drugs were tasked with preventing widespread, illegal sector marijuana trafficking during the transition phase to the legal market equilibrium, they presumably would still have the same likelihood of intercepting illegally traded marijuana at the border or illegally grown marijuana in the national parks. Eventually, the implementation and enforcement of these regulations would rationally shift to resemble that of other legally regulated drugs, such as alcohol and tobacco, for which there is relatively little non-compliance. In the long-run equilibrium for alcohol, for a comparison, we do not see widespread evasion of taxes by producers and distributors, and in the long-run equilibrium for marijuana, too, we expect a high degree of producer compliance.

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[17] Becker et al., (2004), 20-21

There are other ways that evasion could take place, however. For instance, the literature on the market for tobacco shows a well-established trend of cross-border cigarette smuggling. Where tax rates vary between jurisdictions, consumers can individually cross the border to buy cigarettes, but producers can also buy in bulk, smuggle the product back across, and charge a price higher than the cost of smuggling but lower than the local cost within the more heavily taxed jurisdiction. Becker would most likely counter that in this case, the theory has not failed in principle, but the costs to distributors of illegal evasion were too low to alter the basic incentive and competition structure that the distributor faces. This analysis seems quite plausible, and any observed discrepancy in the long run could presumably be attributed to insufficient enforcement against producers and distributors who attempt to evade.

Thus while we cannot be certain that the Becker analysis of optimal tax enforcement would apply perfectly to the case of regulating marijuana, it is very likely that it would, at least in the long-run, because underground firms simply would not be able to compete with regulated legal firms.

Market Differentiation and Supply-Side Incentives to Comply

Among the other three reactions that Nadelmann describes above, it is unclear which effect would dominate with marijuana producers. It seems most likely that domestic producers would simply transition to producing for the retail market. As I will discuss further in section 5 below, a lot of domestic production is currently intended for local consumption. Product differentiation can be extremely profitable to producers, with certain choice strains of medical marijuana in California selling for as high as seventy-five dollars per gram.[18]

As high quality products become more inexpensive to produce, producers would easily be able to pay the taxes and acquire the licenses necessary to produce and create new strains of marijuana, at varying degrees of quality, which will allow consumers who have already begun to exhibit a preference for a higher quality product to further differentiate and control their marijuana use. Think of this in terms of microbrews for beer, or different qualities of wine.

At nearly any store selling beer in the country, you can purchase Budweiser or Coors at a relatively high quantity for a relatively low price, and in terms of its alcohol content, it is a relatively low-quality product. This would quite possibly occur with marijuana as well, where a number of relatively ubiquitous products can be purchased in relatively large quantities for low prices. But additionally, a number of microbrews are produced that vary regionally, by quality, by type of beer, by alcohol-content, and so on. These beers fetch higher prices, and higher profits for brewers.

This is also the case for wine, as differentiation between types of grapes, quality of wine and its age all contribute to make some bottles of wine worth $20 and some bottles worth $2000. This type of market differentiation, which has already started to occur, would be catalyzed further by the shift to a legally regulated market. It would accordingly behoove domestic producers, many of whom are already law-abiding citizens aside from their participation in the marijuana industry, to comply with the legal regulations. Their profits would increase as their product improved in

[18] Samuels, David "Dr. Kush," *The New Yorker*, July 28, 2008

quality or name-recognition—things that they can promote—rather then their success in evading the law.

The Effect of Different Tax and Regulatory Structures

As I have just discussed in section 2, because of the assumption that supply is perfectly elastic in the long run, the type of tax applied makes little difference, but the underlying regulatory structure is still critical.

Federalism and Regulatory License Structures

U.S. policy and politics are notorious for creating a wide amount of variation between states, guaranteed by the Tenth Amendment to the Constitution: "The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people."[19] It is clear that federal law has supremacy on the subject of illicit drugs as it deals with interstate commerce, but if the federal government were to shift to a legally regulated marijuana market, Congress might wish to leave a number of the specific regulatory powers to the states. This follows from the knowledge that the framework under which we are conceiving this shift to regulation is that which currently governs tobacco and alcohol, for which the regulatory structures are varied even at the local and county levels.

Another important feature of federalism as it pertains to regulatory structures and tax revenues is that states are currently the only actors for which there is concentrated movement, albeit incrementally, with regard to policy—the federal government is lagging considerably behind. The growth of the market in California due to its passing of Prop 215 in 1996 is the most well-noted example, but there is a wide-variance between states already with regard to policy, as well as a wide-variance with regard to their capacities for domestic production. The state legislatures in California and Massachusetts, at the time of this writing, moreover, are considering tax and regulation bills. These states would likely benefit disproportionately to others for acting early in the scheme of the federal change in policy.

Most of the regulations, then, that we are assuming will keep costs for producers slightly above the costs of perfect competition (aside from the tax applied) are going to be determined not only by a federal move to regulation but by state-level, and perhaps even local-level policy changes. This makes estimating the revenue generated or the cost imposed on producers extremely challenging, if not impossible, for any of the following potential regulatory options:

- Farm licenses
- Retail distributor licenses
- Personal cultivation licenses
- Permits for recreational use
- Training certification for medical marijuana providers
- Limits to the number of plants that can be grown on a given farm
- Licensing requirements and THC limits for different strains
- Age restrictions and enforcement of such
- Full government production and distribution

[19] U.S. Const. am. 10

Moreover, the data on supply and production, as I will describe in more depth in section 5 below, is extremely crude. The data is simply not sensitive or detailed enough to know how many plants would be an optimal maximum to allow on a given farm, or how much marijuana by weight an average retail distributor might carry at any given time.

The states or the federal government could enact any number of regulatory options from this array—the possibilities are, in many ways, endless. It is accordingly beyond the scope of my estimation procedures, as well as the data available, to attempt to estimate the potential revenue generated from these policies and the costs that these regulations would impose on producers. I assume, then, that some combination of these policies would be enacted at the federal level, but that my above analysis of incentives to comply would hold because the costs of operating legally would still be less than the costs of operating underground.

Optimal Tax Structures and Tax Rates

One issue in determining the appropriate tax to apply is determining what unit of marijuana to tax. Unlike cigarettes, where a unit tax can easily and intuitively be levied on a pack, there is no such standard unit of consumption for marijuana. Much of the literature assumes that all marijuana consumption occurs in the form of a joint. Marijuana is not frequently purchased in terms of joints, however. Far more often the product is purchased "loose," according to respondents of the 2007 National Survey of Drug Use and Health.[20] When asked about the quantity purchased the last time they purchased, respondents typically answer in fractions of an ounce or in grams. As I will explain in section 4, I use the gram as the most appropriate quantity-level for which to determine price, and I accordingly will discuss tax rates, or effective tax rates, in terms of grams as well.

A second important feature of determining the appropriate taxable unit and tax rate is setting a tax optimally. If the tax is set too low, it will not reduce quantity consumed. If the tax is set too high, it could induce evasion if the price exceeds the current, illicit price of marijuana. We expect, also, that as the tax imposed rises, revenue will rise initially, but as the tax continues to rise, consumption will fall, and revenue will eventually decrease, described by the Laffer curve. The optimal tax, then, will accomplish multiple, potentially divergent goals: maximizing revenue, minimizing societal harm from the use of marijuana, chiefly through minimizing quantity consumed, while maintaining incentives for compliance. I discuss issues of optimal taxation at greater length in section 6.

However, I estimate ad-valorem tax rates of 30% through 90% per gram, in increments of 10%, as well as per-gram unit taxes of $2 through $7 per gram in increments of $1. The bills currently pending in California and Massachusetts, respectively, levy taxes of $50 and roughly $200 an ounce.[21] [22] In terms of grams, these taxes are roughly $1.76 per gram and $7.05 per gram. The unit tax range of $2 to $7 per gram, then, is roughly consistent with the current policy considerations.

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[20] NSDUH 2007, Codebook

[21] Mass. Senate No. 1801 Filed 1/16/2009

[22] California AB 390, Filed 2/23/2009

Section 4: Price of Marijuana in the United States

Estimating the price of marijuana in a legally regulated market is challenging for a number of reasons. First of all, there is a considerable amount of uncertainty regarding the current price of marijuana. Data on price are typically limited to a small number of sources, and there is a fair degree of uncertainty regarding the accuracy of this data, and attempting to translate this into an estimate of price in a legally regulated market requires a number of additional assumptions. Despite this uncertainty, there is enough data to create a credible range of estimates regarding the current price of marijuana in the United States, and this data can be augmented with the literature on prices in drug markets generally.

Price is determined by supply and demand. Since I assume that supply in the long run will be perfectly elastic, the price before application of a tax will simply be equal to the marginal cost of production in the regulated market. In this section, I first estimate an index of the current retail price of marijuana, or P_0 from figure 8, section 2. I then use this index of P_0 to estimate a potential range for P_1, the regulated price of marijuana *before* the application of a federal excise tax.

Features of Prices in Illicit Markets

The literature on the functioning of illicit markets yields a number of important insights into how price is determined. Perhaps most importantly, drug prices are very high. By the time the product reaches the retail market, the price will include not only the cost of the raw materials used in production and the cost of labor, but also a premium for illegal import and shipping, risk of product and asset seizures, as well as risk of incarceration for distributors. In addition to the easily observable fact that prices are high in large part due to prohibition, prices vary widely in correlation with a number of variables.

Prices vary based on quantity purchased. Like many other markets, illegal drug markets exhibit significant quantity discounts. For example, the price that a retail consumer will pay to purchase a gram of marijuana is likely to be significantly higher than the price she would pay if she were to purchase an ounce (~28.35 grams). Jeff Desimone used DEA data from 1985 through 2000 to test whether prices at the seller and retail levels follow a multiplicative or an additive model. His results "overwhelmingly reject a multiplicative model," in which the ratio between prices would be constant, and support the additive model, suggesting, rather, that the difference is constant. The primary implication of this work is that "drug enforcement at wholesale levels is less effective in raising retail prices than it would be if the multiplicative model [were] operative."[1]

Whether prices follow an additive or a multiplicative model is directly relevant to estimating the price in a legally regulated market, and thus the tax revenues generated. The fact that marijuana likely follows an additive model not only means that enforcement aimed at decreasing the wholesale price will be less effective, but that the difference between a retail and a wholesale price observed in the current market data is largely what will be reduced in a shift to a regulated market.

[1] Desimone, Jeff. "Illegal Drug Prices" (2005), 72

The intuition behind this, however, is that many of the costs to suppliers that are responsible for increasing price at the retail level under prohibition would be reduced, if not eliminated, in a legally regulated market. The reduced risk associated with prohibition will increase competition in the market as producers can begin to provide the same product for lower prices. In other words, retail prices can be expected to converge, at least to some extent, in the direction of wholesale prices, because the costs of distribution will be significantly reduced. Accordingly, one way to estimate the price in a legal market, which I will discuss and utilize below, is to simply remove the costs added in the illicit distribution of the good.

Prices also vary significantly based on the quality of the marijuana purchased. The quality of marijuana is typically measured by the content of tetrahydrocannabinol (THC), one of the earliest psychoactive ingredients to be identified in marijuana. Gieringer's 1994 report on the economics of marijuana legalization suggest that THC-content of marijuana can range from 2% for the lowest quality product to 15% for the highest. In turn, his report estimates prices at $100-$200 an ounce for the low-THC content marijuana to $400-$600 an ounce for higher quality. This too is not unlike other markets, where consumers are often willing to pay more for products that they deem to be of higher quality.[2] Desimone confirms this variance in price with regard to quality as measured by THC content.[3] There are other dimensions of quality that factor into the price of marijuana as well. Recent evidence from the medical marijuana market in California indicates that there are hundreds of unique strains of marijuana that are being grown and sold, each with unique medicinal properties. Some of these strains have gone for as high as $75/g to patients in California.[4]

Next, prices vary geographically. Once again, this is not unexpected. Like other commodities, as the product moves further from its source of importation or domestic production, there are additional costs that must be factored into the price of the product. This variation is exacerbated in illegal markets, however, because of the additional risk that shipping products long distances entails to wholesale producers and others in the distribution network. While there is limited information on the geographical disparities in price in the American marijuana market, Kenneth Clements has studied this in some depth in Australia and confirms that price varies geographically.[5]

Finally, prices vary over time. Given the limitations to data that I will discuss momentarily, this means that it will probably be helpful to take a price index or average over a number of years, because the data are largely inadequate for applying more rigorous econometric methods to estimating price.

Data on Current Prices

Despite their limitations, there are a number of sources for data on price. Gettman suggests that three of these are reliable, namely: DEA STRIDE data, NSDUH data and High Times magazine data. In addition to these sources, Gettman suggests that anecdotal sources for price data, such as

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[2] Gieringer, Dale. "Economics of Cannabis Legalization", 1994

[3] Desimone, Jeff. "Illegal Drug Prices" (2005)

[4] Samuels, David "Dr. Kush," *The New Yorker*, July 28, 2008

[5] Clements, Kenneth W. "Three Facts About Marijuana Prices," 2004

those found in news articles can be useful.[6] I will utilize all four of these major sources, but before doing so, I will undertake a brief analysis of the relative merits of these data sources.

STRIDE Data

The first major source of data on the price of marijuana is the Federal Drug Enforcement Administration's System to Retrieve Information from Drug Enforcement data set, or STRIDE. This set tracks the prices that undercover officers and informants face when making a purchase or an arrest and seizure. This data set is extremely thorough, offering prices of marijuana, per gram, in three different quantity categories: less than 10 grams, between 10 and 100 grams, and more than 100 grams, based on how much was purchased or seized. This data set is somewhat controversial empirically, however, with some economists suggesting that it is not fit for economic analysis. Horowitz published an opinion to that effect:

> These data are widely used… [but they] are mainly records of acquisitions made to support criminal investigations and are not a random sample of an identifiable population… The STRIDE data on cocaine and heroin prices are not representative of market prices for those drugs. Specifically, there are large differences among price estimates from different subsets of STRIDE. It is concluded that STRIDE is not a reliable source of price data for economic and policy analyses that require accurate measures of price levels and variation.[7]

He does not specifically discuss or analyze how these flaws manifest themselves with regard to the STRIDE data for marijuana, but this does not alter the weight of his critique. The same volume of the Journal of the American Statistical Association published several comments disagreeing with Horowitz, however, as well as rejoinder in which Horowitz defends his original analysis. Caulkins suggests that Horowitz is potentially exaggerating the weaknesses of STRIDE, and says that in fact "it has many appealing characteristics…[including] nominally consistent collection over more than 30 years."[8] Rhodes and Kling further suggest that while "the STRIDE/DMP data suffer from major limitations… Horowitz has not illuminated those limitations, and his dismissal of studies that use STRIDE data are unfounded."[9]

Given this controversy and the limitations of this data, it is a question of paramount importance for the sake of this analysis to attempt to understand how these data are biased and to what extent they may be representative of the distribution of prices in the market. The issue of non-random sampling suggests that the STRIDE data are not a representative distribution of prices. Grogger comments:

> It seems implausible that the distribution of prices from STRIDE could reflect the distribution of market prices for illegal drugs, because the sampling strategy is a complex function of the agencies' objectives and constraints.[10]

This makes sense to some degree, because when drug enforcement officers are making undercover purchases, their individual incentives, as well as their agency's incentives are not to

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[6] Gettman, Jon. "Lost Taxes", 2007, 22
[7] Horowitz., "Should the STRIDE data be used…," 1254
[8] Caulkins., "Should the STRIDE data be used…," 1264
[9] Rhoades and Kling, "Should the STRIDE data be used…, " 1266
[10] Grogger, "Should the STRIDE data be used…," 1269

collect data on prices—they are, rather, attempting to apprehend criminal suspects. This complexity could certainly cause this data to be unrepresentative, particularly if officers' incentives prevent them from attempting to make low quantity-level purchases as opposed to purchases of greater quantities, or causes them to disregard quality of the drug. If this effect holds, it would bias the resulting price estimates downward—they would understate the true average price of marijuana on the market.

Police also may have some inherent disadvantage in buying drugs that stems from the fact that they are, most likely, unknown to the person from whom they are buying drugs. Moreover, this could be particularly true in the case of the STRIDE marijuana price data because the literature suggests that a very large number of marijuana users acquire marijuana through social sources. Police would be particularly disadvantaged in this case, and if this effect holds, it would bias the resulting price estimates upwards—it would overstate the true average price of marijuana on the market.

Rhodes and Kling suggest, however, that with regard to cocaine and heroin, "police are not especially disadvantaged purchasers. However, like other buyers, they experience considerable variation in product quality."[11]

On net, therefore, it is possible that the STRIDE data are biased upward, but this is at best a weakly supported assumption. Regardless of the uncertainty with respect to the bias of the STRIDE price estimates, however, and regardless of the controversy surrounding their use in economic analysis, the data is ubiquitously utilized in the drug literature. Recognizing these limitations, I include these price observations in calculating a retail price index.

NSDUH Data

Another major source of data is the National Survey on Drug Use and Health, or NSDUH.[12] As recently as 2007, this survey has asked respondents questions about their drug use, including basic questions on marijuana consumption (whether they have used marijuana in the last month or year) and questions on the amount purchased and price paid at the time of their last purchased. It is, accordingly, possible to derive prices in the market using this data.

Deriving price indices from this data, however, suffers from similar methodological flaws as does estimating demand-side models of quantity from this data. I discuss the limitations for deriving consumption estimates from this data in detail in section 5, and I eventually dismiss the resulting estimates of quantity. In short, however, the NSDUH data relies on respondents' truthful reporting of their behavior with regard to marijuana. Because of the illegality of the drug, respondents have an incentive to intentionally report the answer to these questions inaccurately. Moreover, many users, casual or otherwise, may not remember accurately the last time they bought marijuana, how much they paid for it and so on. Thus in addition to intentional misreporting, there is likely to be measurement error due to unintentional misreporting of data.

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[11] Rhoades and Kling, "Should the STRIDE data be used…, " 1265

[12] Before 2002, the NSDUH was titled the National Household Survey on Drug Abuse. Generally throughout my analysis, NSDUH and NHSDA are interchangeably used to refer to this data set collected by the U.S. Department of Health and Human Services.

Gettman uses this data to derive price indices, but readily admits that the NSDUH data provides "at best… a minimum number of drug users in the country."[13] Thus acknowledging that a large number of drug users are not included for whatever reason, it follows that the measurement error with regard to price could also bias any estimated price index downward. A quick overview of the codebook for the NSDUH 2007 dataset reinforces the idea that there are a large percentage of "legitimate skips" for these questions, or people who actively chose not to answer.[14]

Despite these limitations, Gettman uses NSDUH data to derive both retail and producer price indices in his 2006 report.[15] He derives these indices for the five-year period from 2001 through 2005 and does so in a two-stage process:

> Midpoint prices per gram were derived for each category of purchases of less than one ounce, and a weighted price per gram was calculated with data from each of the last five years of survey data…Stage Two involved reducing the Pound price index from a retail index to a producer level index. The producer index was calculated at 58.75% of retail value. The framework producing this figure was based on assumptions that a wholesale price would be 83.5% of retail, a distributor price would be 67.5% of retail and a farm price would be at 50% of retail, and that the producer price index would be set at halfway between the farm and distributor prices to reflect difference sin supply networks in terms of the number of intermediaries between end-use customers and producers.

While this work on domestic production successfully used the "conservative parameters"[16] Gettman describes, the resulting indices are likely to be systematically understated for the reasons mentioned above. He even specifically allows for this possibility, noting that the price level is conservative in relation to "frequent reports from police that value seized marijuana between $2000 and $4000 per pound."[17] The producer price index could be even further underestimated, as it seems to infer that marijuana prices between levels of distribution follow a multiplicative model rather than the additive model that DeSimone finds applicable.

Once again, recognizing these limitations, I include Gettman's price indices[18] in my price estimates, for the same reason that I include the STRIDE data. Namely, it serves, at worst, to bias my estimates downward, ultimately producing a more conservative estimate of the tax revenue from a regulated marijuana market.

High Times Magazine Data

High Times magazine regularly asks price information from readers and compiles a monthly index on marijuana prices.[19] At first it may seem that this data is far less fit then the NSDUH or the STRIDE price data for use in an economic analysis, but I argue otherwise for several reasons.

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[13] Gettman, Jon. "Lost Taxes", 2007, 10

[14] NSDUH 2007, ICPSR

[15] Gettman, Jon. "Marijuana Production," 2006, 9

[16] Gettman, Jon. "Marijuana Production," 2006, 7

[17] ibid.

[18] Gettman's final retail price index, derived from the NSDUH data, is inconsistent between his 2006 report on Marijuana production in which he first derives it and his 2007 report on taxes in which he utilizes for analysis comparably to how I utilize it here. I used the more recent iteration, from 2007, which, unlike the index from 2006, consistently applies gram to ounce to pound price conversions.

[19] Gettman, Jon. "Lost Taxes", 2007, 22-23

First, as I have just discussed, both the STRIDE and NSDUH-based price estimates are likely to bias price estimates downward. Next, however, the High Times data has the unique feature by which it creates a per-ounce price index that is divided into different quality levels. No other data does this, and so inclusion of the High Times Magazine data, to some extent at least, is necessary to capture the variance in price caused by the variance in the quality of marijuana on the market. Lastly, the data is provided by the readership of High Times magazine. This is a double-edged sword, of sorts, because this selection means, ceteris paribus, that the data is not a random sample. However, the benefit of this data is that it might capture a large section of the marijuana industry that is not captured by the NSDUH or STRIDE data sets. These features make the High Times data useful, at the very least, and perhaps necessary to crafting a credible estimate of the price of marijuana.

Anecdotal Price Data

A CNBC original program entitled *Marijuana Inc.,* recently reported on the market in California's Mendocino County. The program suggested that the marijuana industry in Mendocino, part of California's "Emerald Triangle," could account for up to 66% of the economy in the county. The large number of growers in the area and the relative lack of risk to small producers makes the marijuana market in Mendocino county as competitive a market as can be currently observed in the United States. Standard economic theory tells us that under perfect competition, price of a good should equal the marginal cost of production. Even for this relatively competitive market, the program implies a retail price of $13.22/gram ($6000/pound) and they estimate the cost of production at closer to $0.88/gram ($400/pound).[20]

A New Yorker article by David Samuels on California's medical marijuana industry also relayed several prices observed in the market. Samuels relays a broker shouting into a phone "I can do three-twenty-five" an ounce,[21] or $11.61/g, a dispensary "recommending two strains, which cost sixty-five dollars for an eight,"[22] $520 an ounce or $18.60/gram, and a menu at one dispensary selling some strains for an astonishing "seventy-five dollars per gram."[23]

I do use neither the CNBC nor the New Yorker data to construct my estimate of P_0 or P_1, but they serve as a useful reminder that none of these sources of data mentioned above is perfect, but some seem more flawed then others. Accordingly, my final estimate will be weighted by source, as described below.

Previous Estimates of Price

Taking these three main sources, (STRIDE, NSDUH and High Times data) from 2003 through 2006, Gettman estimates a four-year average price in 2007 dollars of $7.87 per gram.[24] I will also use these sources. I have already discussed why the Gettman estimate of $7.87 per gram estimate is likely an underestimate, but one more example helps to clarify a key assumption.

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[20] CNBC Marijuana Inc.,
[21] Samuels, David "Dr. Kush," *The New Yorker*, July 28, 2008
[22] ibid.
[23] ibid.
[24] Gettman, Jon. "Lost Taxes", 2007, 24

The STRIDE data differentiate by quantity purchased. Gettman uses the 2003 average of the 10 to 100 gram range, which STRIDE data evaluates at 26 grams, or about .9 ounces. The price for purchases of less than 10 grams was estimated at 11.37 in 2002 dollars, however, and in 2007 dollars this would be $13.04 per gram.[25]

In this report, I utilize the price per gram, rather then the price per ounce, in estimating current retail price and the prices in a regulated market. If a retail purchase is defined as a purchase for personal consumption, this is somewhat counter intuitive, as the majority of users seem to purchase marijuana in fractions of an ounce, rather than in grams. However, in a legally regulated market, the quantity purchased during the average purchase will best be described in increments of a gram because of the product differentiation described in the previous section. Users will be able to buy an infinitely greater number of different strains and brands of marijuana, some more or less expensive than others. But like the closest markets to a legally regulated market, namely the Netherlands and some medical marijuana regimes, purchases of a gram are common because users can diversify the strains that they consume. Ultimately, this assumption relates directly to my estimate of P_0, but less so to my estimated range for P_1.

Estimates of Price in the Current Market

I present my price indices for the current retail price and pre-tax, regulated prices in tables 1, 2 and 3 respectively. In Appendix A, I present my source data as adapted from STRIDE, NSDUH/Gettman and High Times Magazine.

Table 1

Current Retail Price Index, 2007 Dollars				
Source	**Unweighted**	**Weight 1**	**Weight 2**	**Best-weight**
Gettman/NSDUH	$6.81	15%	20%	15%
STRIDE - 10 year average, <10g	$10.29	25%	35%	45%
High Times	$12.75	30%	35%	30%
High Times - high quality	$16.45	30%	10%	10%
10-year Average Price Index	$11.58	$12.36	$11.07	**$11.12**

To deal with the variation in the quality of these sources for price data, I create simple weights to derive a weighted, average price for the 10-year period from 1997-2007, shown in 2007 dollars. STRIDE is given the most weight because of its well-established place in the literature (however controversial), and is weighted at 45%. I use both the High Times "Current U.S." price index, weighted at 30%, and the High Times "Kind," or high quality index, weighted at 10%. The latter accounts for the consistently increasing quality of marijuana on the market, expecting that quality will continue to increase in a competitive market. I discuss quality further in section 5. Finally I include the Gettman/NSDUH retail index average weighted at 15%. Table 1 displays these weights, an unweighted average, and two alternative weights. My estimate, then, for the current retail price of marijuana is $11.12 per gram.

[25] I use the Consumer Price Index data to calculate all values in 2007 dollars.

Estimates of Price in a Legal Market

Clearly, since the goal is to estimate potential tax revenue in a legally regulated market, current prices are only important insofar as they intimate what the pre-tax price would be in a legally regulated market. Miron roughly estimates the legal price by observing retail prices in the Netherlands. Since the average retail price there is approximately 50-100 percent of U.S. prices, he assumes that U.S. prices would not be likely to drop more than 50 percent, and uses this benchmark to estimate the budgetary impact.

He discusses the notion that price might not fall that much in greater depth in his 2004 book, *Drug War Crimes*:

> Black market suppliers can easily evade government regulations and taxes… These cost savings offset some of the increased costs caused by prohibition… A related reason prohibition might have a weak effect on costs is that the efficacy of enforcement expenditure is plausibly greater for taxation and regulation policies than for prohibition.[26]

He adds that prohibition causes firms to face no costs of advertising, and to facilitate evasion of anti-trust laws, increasing market power for suppliers.[27] Thus while it seems that under legally regulated conditions, price should fall, Miron argues very effectively that it might not fall more than 50 percent.

Importantly, however, Miron does not estimate price and quantity to derive his estimate of the potential tax revenue in "Budgetary Implications." Rather, he uses a 2002 Office of National Drug Control Policy estimate of U.S. "expenditure" on marijuana. I discuss the flaw of this ONDCP report specifically in section 5, but this does not affect the validity of Miron's assertion that price might not fall more than 50%. If the regulatory structures discussed previously, before a tax, impose roughly similar costs on US producers as the regulatory structures in the Netherlands do for Dutch producers, this method will be a valid means of estimating a pre-tax price. Table 2 shows the weighted averages from table 1, discounted to 35%, 50% and 65% of current price.

Table 2

Pre-Tax, Regulated Price as a Percentage of Current Price				
	Unweighted	**Weight 1**	**Weight 2**	**Best-Weight**
35%	$4.05	$4.32	$3.88	$3.89
50%	$5.79	$6.18	$5.54	$5.56
65%	$7.52	$8.03	$7.20	$7.23

Another way to estimate the price in a legally regulated market, as I intimated previously in this section, is to make the simplifying assumption that the costs of distribution—of getting the

[26] Miron, Jeffrey A. *Drug War Crimes*, 2004, 8
[27] ibid. 9

product from the farm or wholesale level to the retail level would effectively disappear under a legally regulated market. The price that remains would effectively consist of the marginal cost of the product, which would include the cost of compliance with the legal regulations. This is a simplifying assumption because it means that all things being equal, the current wholesale price could be considered the pre-tax price in a legally regulated market.

Table 3

Pre-Tax, Regulated Price as Current Wholesale Price		
Source	**Unweighted**	**Weight**
STRIDE >100g, 10-year average	$2.58	55%
Gettman Farm	$3.41	20%
Gettman Index	$4.00	15%
High Times "Schwag"	$3.46	10%
Current Average, 2007 dollars	$3.36	$3.05
Combined-Method Minimum:	$1.68	$1.52

Table 3 presents a weighted, wholesale price index. The STRIDE data is again given the most weight, with the >100 gram category weighted at 55%. I include the Gettman/NSDUH "farm" index, weighted at 20% and his overall index, weighted at 15%. I weight the High Times "schwag," or lowest quality index, at 10% to account for the potential availability of large quantities of low quality marijuana for a low price in a regulated market. The unweighted average of these wholesale, current prices is $3.36 per gram and the weighted average is $3.05 per gram.

To create a valid floor for the pre-tax, regulated price of marijuana, I combine these two methods. The resulting range of pre-tax regulated price is $1.52 per gram for a minimum, $3.05 per gram for the best guess and $7.23 per gram as a maximum pre-tax price estimate for a regulated market.

Section 5: Quantity of Marijuana in the United States

Similar to the challenges in estimating the price of marijuana in the U.S. market, estimating quantity is complex and requires a number of assumptions. Data on the quantity consumed is as scarce, if not more so, than data on the price of marijuana, perhaps even more unreliable. Whereas in the current market, law enforcement officers at the state and federal level can make undercover purchases, revealing a specific price paid at a given moment in time, there is no mechanism to collect data on the aggregate quantity of the market for this particular agricultural product. Due to the illegal nature of the market, there is, at best, limited data on how many foreign and domestic producers exist and supply marijuana to the market. Moreover, the data is similarly limited in terms of our knowledge of how many Americans consume marijuana and the characteristics of that consumption.

Methods for Estimating Quantity

Traditional indicators of the scope of a market are not useful in the analysis of drug markets, or any illicit markets. This leaves room for two contrasting methods of estimating the scope, namely, through supply and demand. The literature on the marijuana market utilizes these two methods of estimating the quantity of marijuana in the U.S. market. Supply-based estimates of quantity in the U.S. market rely on "data on foreign production, observations about domestic production, and data used in federal inter-agency studies and reports."[1] Demand-based estimates utilize consumption data, estimating quantity from survey results in which individuals report how often they use marijuana, whether they have used in the past month, and so on.

Both supply- and demand-based methods for estimating quantity have significant flaws. Critics might contend that neither is fit for economic analysis of the domestic marijuana market. In this study, then, I will use only supply-based methods, because as I will describe, the flaws in the demand (consumption) data seem more detrimental to accurate analysis of the market than the flaws of the supply-based method.

Supply-side Estimates of Quantity

In studies utilizing supply-side data, estimates of foreign production are usually taken from federal seizures of marijuana, from any number of agencies such as U.S. Customs and the Drug Enforcement Agency. Estimates and observations on domestic production stem almost solely from plant eradication data. Finally, various governmental reports yield additional insight into the way government officials observe trends and use information that might not be publicly available. These reports also include publicly available data on production in countries known to be suppliers of drugs, and specifically marijuana and other cannabis derivatives, to the United States.

With regard to foreign source marijuana, federal seizure data is typically assumed to be nearly all from imported sources.[2] Considering that many of the federal agencies that seize marijuana (and other drugs) are specifically tasked with protecting the U.S. border (e.g. U.S. Customs or U.S. Border Patrol), it is possible that this is true. But there is also likely to be, at least, some small

[1] Gettman, Jon. "Lost Taxes," 2007, 25
[2] Hudson, Rex. "Marijuana Availability"

fraction of the seized product that was produced domestically. That said, by applying a seizure rate, or range thereof, we can get a crude picture of the range of foreign supply on the market. To gain a fuller understanding of the foreign supply of marijuana to the United States, then, it can be helpful to augment seizure data and compare it with governmental reports on production in source countries.

For domestic production, plant eradication data can complement estimates of imported marijuana to yield estimates of the entire domestic market. The Drug Enforcement Agency reports the number of outdoor and indoor grown plants that it eradicates each year. By applying an estimated yield per-plant, and a plant-seizure rate, this data can be translated into an estimate of the quantity on the market that is produced domestically. Ultimately, by applying a ratio of imported to domestically produced marijuana on the market, supply-side methods can yield an estimate of the quantity of marijuana currently on the U.S. market.

The supply-side data is, admittedly, problematic. It requires a number of assumptions, or ranges of assumptions to be formed into an estimate of the overall market. For some of these assumptions, there is supporting evidence that suggests that they are reasonable, but the data on the various seizure rates, import-export ratios, and so on, are all necessarily "best-guesses," given the discreet nature of the marijuana industry. Furthermore, the observations (pounds of marijuana seized, plants eradicated, etc.) are likely to be endogenous to levels of enforcement. This further complicates the assumptions required by the data, because it is possible that large quantities of supply (for example, imports from Canada) are not being tracked as heavily as other large quantities of supply (imports from Mexico.) In turn, all of these assumptions naturally serve to weaken any economic analysis of the U.S. marijuana market that utilizes supply-side estimation techniques. As I will show, however, though imperfect indicators of aggregate quantity consumed, supply-side techniques are still preferable to demand-side techniques.

Demand-Side Estimates of Quantity

Demand-side estimates are almost always derived from nationally representative survey data, and specifically the NSDUH. The NSDUH asks respondents whether or not they have used marijuana ever, in the past year and in the past month, as well a limited number of other questions. Additionally, the survey used to ask respondents further questions, exploring the frequency, quantity and other important characteristics of marijuana use. Given this data, it is hypothetically possible to estimate the quantity that would have to be available on the market to support the self-reported consumption of respondents. This method, however, will consistently and systematically underreport the quantity in the market. A brief exploration of existing consumption (demand-side) estimates illustrates this detrimental flaw.

A December 2002 report by the Drug Availability Steering Committee of the Federal Drug Enforcement Agency discusses some of the challenges of estimating marijuana availability, or supply, using consumption models. It specifically criticizes an Office of National Drug Policy Study from two years prior, entitled "What America's Users Spend on Drugs, 1988-2000." That study estimated that a total of 927 metric tons of marijuana were consumed by American consumers annually, but according to the later DEA report, suffered from a number of fatal flaws.

1) *Inaccurate Measure of the Number of Marijuana Users*

Relying on NHSDA data for an estimate of the number of lifetime, annual or monthly users is necessary to model the quantity of marijuana consumed annually in the United States, but the DEA paper is quick to reinforce the fact that drug "users may knowingly or unknowingly misrepresent the frequency or severity of their drug use."[3] This measurement error would cause the estimated number of users to be biased heavily downward. Following a change in methodology in 2002, the number of self-reported marijuana users jumped sharply in the NHSDA/NSDUH data, from approximately 21 million annual users to approximately 25 million. And even still, this is likely to be systematically underestimated. Gettman, for instance, suggests that the true number of users could be as high as 41 million.[4]

2) *Lack of Data on Quantity and Frequency of Use*

Different users of marijuana almost certainly have different characteristics of use. At first thought, this is obvious, as we would not expect two people who differ both observably (age, race, gender, weight) as well as unobservably (preferences for achieving a certain subjective "high", tolerance to marijuana) to consume marijuana at the same rate. But the data on rates of consumption is extremely limited, primarily because the NHSDA "stopped questioning users about the number of joints they used in 1994."[5] Even if this 1994 data has not changed, and all marijuana users did consume the same number of joints in a given time period (which are highly unlikely assumptions), "the amount of marijuana in a joint is not fixed." Additionally, "marijuana may be consumed in forms other than the joint (e.g., via a bong or blunt)."[6] Furthermore, many consumers use marijuana in social settings in which a joint, a bong or a blunt is shared. In these settings it is nearly impossible to calculate the quantity of marijuana consumed by any given user in any single usage.

3) *Lack of Data on the Demand Response to Quality*

The fact that data on frequency and quantity of consumption has not been collected since 1994 also makes it nearly impossible to gauge how consumption has changed in reaction to changes in the quality of marijuana on the market. It has been well documented that quality, as measured by the average THC content of both low- and high-quality marijuana has been on the rise over the past 20 years. From 1997 through 2000, the potency of commercial grade marijuana, as measured by THC content, increased from 4.25% to 4.92%, and the potency of high quality marijuana (sinsemilla) increased from 11.62% to 13.2%.[7] The United Nations Office of Drugs and Crime World Drug Report 2008 also confirms this trend. As measured by THC content, the potency of average marijuana seized in the United States went from 5.3% in 2000 to 8.8% in 2006.[8] The Library of Congress' Federal Research Division also addresses this issue:

> The average potency of samples of all cannabis types increased from 3.00 percent in 1991 to 5.23 percent in 2001. When categorized by type, potency generally increased from 3.09 percent to 5.01 percent for commercial-grade marijuana during the same period, but fluctuated for sinsemilla. The concentration of THC in sinsemilla averaged 10.53 percent in 1991, dipped to a low of 5.77

[3] Drug Availability in the United States, 2002, 123
[4] Gettman, Jon. "Lost Taxes", 2007, 11
[5] Drug Availability in the United States, 2002, 138
[6] Drug Availability in the United States, 2002, 139
[7] Drug Availability in the United States, 2002, 138
[8] World Drug Report 2008, UNODC

> percent in 1993, and increased steadily to a peak of 13.38 percent in 1999 before declining to 9.1 percent in 2001. Those figures indicate how dramatically the average THC content of commercial-grade and sinsemilla marijuana has risen since 1988... The sharp increase in THC content is explained in part because of improved techniques for growing cannabis indoors.[9]

Without more recent data, therefore, any model estimating consumption with the 1994 data has absolutely no way to estimate the impact of the availability of an increasingly higher quality product on the market.

In his 2007 paper, "Lost Taxes and Other Costs of Marijuana Laws," in addition to utilizing supply-side estimates, Jon Gettman creates a more refined consumption model. Noting the inconsistency of the 2002 ONDCP report with supply-side estimates, Gettman updates the consumption model to account for:

- All 25 million annual marijuana users (not just monthly users) and inflates this to account for under- and non-reporting.
- An increased average weight of a joint (from .4 grams to .75 grams)
- NSDUH data on frequency of use, quantity of use, and differences between male and female use trends

Using this significantly improved estimate, Gettman claims that "Americans consumed at least 9,830 metric tons of marijuana in 2005."[10] This is a far more accurate estimate than the ONDCP report from 2002, yet this figure should still be viewed skeptically. As Gettman notes, the "questions soliciting... data on consumption amounts and frequency were discontinued after the 1993 survey."[11] This necessarily limits the relevance of this consumption model in light of the documented changes in the quality of marijuana on the market, and the potential for the characteristics of consumption to have changed over the past fifteen years. Gettman's model does not attempt to account for methods of using marijuana other than the joint, the social nature of marijuana usage or the observable demographic variation in use by categories other than gender. Most notably, Gettman fails to differentiate consumption by age, which is undoubtedly critical in determining how much is consumed by a given user in a typical use.

Ultimately, as much as Gettman's consumption model is a vast improvement on the 2002 governmental models, it is still inconsistently lower than seizure or eradication-based estimates of supply in the domestic market, and is accordingly likely to systematically underestimate marijuana consumption in the United States.

Given the severe limitations of even the best demand-side models, I will not be utilizing demand-side estimation techniques. Hudson also does not use consumption modeling to estimate the quantity in the current market. They describe their reasoning as follows (emphasis added):

> No exact estimates of the amount of marijuana available in the United States have been made, and there are no reliable estimates for domestic production. The widespread, clandestine cultivation and production of marijuana at indoor and outdoor sites in the United States and the lack of

[9] Hudson, Rex. "Marijuana Availability," 6
[10] Gettman, Jon. "Lost Taxes", 2007, 32
[11] Gettman, Jon. "Lost Taxes", 2007, 31

> cannabis cultivation monitoring systems and surveys make it impossible to have an accurate assessment of the location and extent of cultivation and production. Drug-trafficking organizations in four countries--Mexico, Colombia, Canada and Jamaica--supply most of the foreign-produced marijuana available in the United States. Thus*, the only data that can provide limited insight into marijuana availability are eradication and seizure statistics*.[12] (emphasis added)

Ultimately, the exclusion of demand-side consumption estimates will yield a wide range of estimates of the supply in the U.S. market that are greater than previous estimates, but this range is still likely to be underestimated due to the use of conservative parameters and assumptions.

As I discussed at length in section 2, the theoretical impact on quantity of the shift to a regulated marijuana market is highly dependent on the elasticity of demand, and perhaps even more so because of my assumptions of perfectly elastic long-run supply and no shift in demand. Before presenting my quantity estimates, then, it is important to discuss the elasticity of demand.

Marijuana Dependence and Its Effect on Elasticity

Perhaps the greatest confounding factor with regards to estimating the elasticity of any drug, legal or illegal, is the fact that the demand for drugs is defined not only by the utility of any given use, but by the fact that drugs are addictive, or cause dependence among those who use them. The literature on cigarettes has long recognized this, for example, and there is a great deal of literature exploring how to economically understand addiction. Whether consumers follow a rational addiction model, such as that put forth by Becker and Murphy, a myopic model, or simply have time-inconsistent preferences, will have an impact on the way that consumption behavior reacts to changes in price. How we understand addiction, too, can lead to vastly different conclusions as to the most economically sound policy alternatives, particularly when addiction is seen as a market failure.

Marijuana, however, is a unique drug and has unique pharmacological properties. While there is certainly some debate as to whether or not it should be defined as addictive, it is somewhat widely accepted that the addictive properties of marijuana are less than those of nicotine, opiates and other drugs. According to one report:

> The risk of dependence is around 9% among persons who have ever used cannabis…and around one in six for young people who initiative in adolescence…these risks compare with risks of 32% for nicotine, 23% for heroin, 17% for cocaine, 15% for alcohol, and 11% for stimulant users.[13]

This lower level of dependence tends to suggest that across the board, marijuana consumption should be more responsive to price, or more elastic, than the consumption of other drugs.

Understanding the relationship between the addictive properties of marijuana and the elasticity of demand is further complicated by the fact that "the common symptoms observed with cannabis withdrawal are primarily emotional and behavioral,"[14] and not as significantly physical as in the case of cigarettes or opiates. This also suggests, however, that marijuana should be more responsive to price than other drugs.

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[12] Hudson, Rex. "Marijuana Availability," 22

[13] Room et al., Global Cannabis Commission Report, 33

[14] Budney and Hughes, "The Cannabis Withdrawal Syndrome," 2006

There is some literature that discusses the complementary effects between marijuana and cigarettes. Farrelly uses NHSDA data and legal marijuana price indicators (but not price) to show that "higher cigarette taxes appear to decrease the intensity of marijuana use."[15] Chaloupka uses Monitoring the Future survey data of 8th, 10th and 12th grade students to estimate cross-price elasticities, and confirms that higher cigarette prices reduce the average level of marijuana used by current users.

I will discuss these cross-elasticities with respect to health in section 7. In determining a constant elasticity, however, it will suffice to say that given the literature on marijuana dependence, the elasticity of demand is likely to be slightly greater, or more elastic, in absolute value than that of cigarettes, and the two are likely to show complementary effects. This will be critical to estimating a credible range of the elasticity of demand for marijuana.

Estimates of Price Elasticity of Demand for Marijuana

Intuitively, for any given marijuana user, his price elasticity of demand is likely to be highly correlated with various observable and unobservable characteristics about him. For example, there is likely to be a correlation between elasticity and age. The average college student's consumption behavior with regard to marijuana will probably not be the same as the average middle-aged schoolteacher's behavior or the average retiree. Elasticity might exhibit a sort of bell-curve in relationship to age, where consumption behavior is most responsive to price (most elastic) in one's prime working years, when the opportunity cost of the time spent using marijuana is highest, or if marijuana users become highly dependent over time, elasticity could be highest for young users and decrease over the lifespan, as the literature suggests for cigarettes.

Variance in elasticity should also exhibit itself strongly with regard to frequency or quantity of use, as well as quality of marijuana available as well. Casual users are likely to have a more elastic demand response to a change in price whereas heavy users might simply be happy to reduce their costs, implying a relatively inelastic demand. Similarly, as quality of marijuana increases, less marijuana needs to be purchased by any given user if the goal of consumption to achieve some subjective "high".

The elasticity response between time-periods is perhaps an even more critical factor. If consumers follow some sort of rational addiction model in which consumption is dependent on past price, future price, and current price, such as the Becker-Murphy framework, this will clearly effect both the participation and unconditional price elasticity of demand for current marijuana users.

Importantly, however, regardless of the fact that the price elasticity of demand should be correlated with various observable and unobservable characteristics of any user, the elasticity of participation is distinct from the response of how much to consume conditional on participation, or the conditional elasticity. The literature for cigarettes distinguishes these by estimating two types of elasticities: participation elasticities and unconditional elasticities. Participation

[15] Farrelly et al., "Joint Demand for Cigarettes and Marijuana", 2001

elasticity refers to the dichotomous participation decision—whether or not to consume the good at a given price, regardless of quantity. Unconditional elasticity, or total elasticity, on the other hand, is defined as "the sum of the price elasticity of participation and the price elasticity of the number of cigarettes smoked conditional on positive smoking."[16]

Here it is important once again to remember the distinction between demand shifting outward and an increase in quantity consumed. We are interested in an unconditional elasticity for marijuana because some consumers will still be induced by lower prices to initiate consumption of marijuana. This is expected, as they are already represented by the illicit market demand curve, but their reservation price has not yet been met. The influx of new users, *dependent on price*, therefore, does not alter the assumption that demand will not shift.

Nisbet and Vakil estimate the elasticity of demand for marijuana among college students to be in the range of -.4 to -1.5, with an elasticity of "slightly greater than 1" yielding a reasonable estimate.[17] Miron qualifies this slightly downward, suggesting that the elasticity of demand is "at least -0.5 and plausibly more than -1.0," according to data from the Netherlands and the Nisbet and Vakil estimates.[18] He effectively uses an elasticity of -.75 as a conservative measure, "since the decline in price is unlikely to exceed 50% and the demand elasticity is likely at least -0.5."[19] But he recognizes, however, that "if the price decline is noticeable… [and elasticity] is greater than or equal to 1.0 in absolute value, then expenditure will remain constant or increase."[20]

Grossman cites Pacula's participation price elasticity estimates for marijuana in his 2004 working paper at a range of -.3 to -.69, but notes that Pacula's upper-bound figure "may be too-small given the measurement error in price discussed in the study."[21] He does not cite any unconditional elasticities of demand for marijuana. Chaloupka estimates conditional cross-price elasticities between cigarettes and marijuana, respectively, at -.73 and -.84, "for a total elasticity of -1.57," which is larger than the unconditional elasticity for cigarettes alone of -1.13.[22] This literature, because of the obvious limitations of the data, does not try to differentiate greatly between time periods or based on user characteristics. It is necessary, then, to use a constant elasticity of demand simply because of the uncertainty of the range of elasticity and how that varies over time and user characteristics. A comparison with data on the elasticity of cigarettes, however, suggests that the Nisbet and Vakil, and Miron estimates provide a reasonable frame for the estimates of price elasticity of demand for marijuana.

Due to complementary nature of the goods, and the fact that they both have addictive properties, another useful way to estimate the total elasticity of demand for marijuana is to base it off of estimates of the unconditional elasticity of demand for cigarettes. Grossman summarizes both participation and unconditional elasticities of demand for cigarettes by age from a number of studies. Table 4 shows just the unconditional elasticity estimates adapted from Grossman's

[16] Grossman, 2004, p22
[17] Nisbet and Vakil, 1972
[18] Miron, Jeffrey A. "Budgetary Implications," 2005
[19] Miron, Jeffrey A. "Budgetary Implications," 2005, 14
[20] Miron, Jeffrey A. "Budgetary Implications," 2005, 13
[21] Grossman, 2004, 24
[22] Farrelly et al., 2001, 54

summary.

Table 4

Cigarette Price Elasticity Estimates - Unconditional, by Age					
	Age 12-17	**Age 18+**			
Source					
Lewit, Coate and Grossman (1981)	-1.45				
Lewit and Coate (1982)		-0.94	-0.48	-0.3	
Chaloupka and Grossman (1996)	-1.31				
Chaloupka and Wechsler (1997)		-1.12			
Lewit et al. (1997)					
Evans and Farrelly (1998)		-0.63	-0.42		
Harris and Chan (1999)	-1	-0.78	-0.64	-0.66	-0.32
Gruber and Zinman (2001)					
Average Unconditional Elasticity	-1.2533	-0.6009			

Adapted from Grossman, 2004, Table 5

To create an estimate of the elasticity of demand for marijuana based on cigarette price elasticities, I first divided the estimates into two age categories, defined as 12 to 17 years of age, and 18 years of age and older. I then took each observation of the unconditional elasticity of demand and placed it into the proper age category.[23]

Next, I inflate these averages by a rather crude "addictiveness ratio." Elasticity of a good should decrease as the level of addiction or dependence that it causes increases. As I discussed above, we expect that marijuana is less addictive and generates less physical dependence than cigarettes do. We also know that they are complements, however, so it is likely that their elasticities are not dramatically different. My "addictiveness ratio," then, simply inflates the above meta-average of price elasticity of demand for marijuana by some percentage, which can be understood as how much less addictive marijuana is compared to cigarettes. An addictiveness ratio of .1, accordingly, simply inflates the stated estimate of the price elasticity of cigarettes estimate by 10% to estimate the price elasticity of marijuana.

Table 5 inflates the averages from the two age groups above by ratios of 5% through 45%.

[23] The only exception to this is that I excluded the Evans and Farrelly (1998) estimates of "40+" and "18+" as apparent outliers.

Table 5

Elasticity Estimates with Addictiveness Ratio			
	Unconditional Price Elasticity of Demand		
Addictiveness Ratio	Age 12-17	Age 18+	Weighted
5%	-1.3160	-0.6310	-0.7200
15%	-1.4413	-0.6910	-0.7886
25%	-1.5667	-0.7511	-0.8572
35%	-1.6920	-0.8112	-0.9257
45%	-1.8173	-0.8713	-0.9943

Finally, to calculate the final range of the price-elasticity of demand for marijuana, I weighted the two age-group observations for the unconditional elasticity based on the estimated percentage of consumption that occurs in each age group. Gettman's 2008 estimate, based on NSDUH data, suggested that 87% of annual consumers were "adults."[24] Accordingly I weighted the 18+-age category at .87 and the 12-17 category at .13.

The resulting range of estimates that I use is -0.857 as a best guess, with a sensitivity range of -0.72 to -0.994. This range is well within the Nisbet and Vakil estimate, and conservative compared to their assertion that a reasonable estimate might be "slightly greater than 1" in absolute value.[25]

The results of estimating a range of elasticity based on the demand for cigarettes in this fashion is not statistically rigorous, but in my opinion, conforms with the spirit of the literature. It is a conservative estimate compared to the Nisbet and Vakil estimate. The lower bound, -0.72 is slightly lower than Miron's implied elasticity of -0.75.

And it would be surprising if marijuana were in fact only twenty-five percent less addictive than cigarettes, as my best guess assumes. The impact of the higher elasticity of demand for youth is potentially worrisome, and I discuss this at greater length in section 7, but regardless, the resulting range of the elasticity of demand is narrow enough to be credible, and well within the bounds of the existing literature.

Estimates of Quantity in the Current Market – Q_0

The two primary sources to estimate quantity available currently, from the supply-side, are seizure and eradication data. Respectively, these two sources of data reflect two sources of the supply of marijuana, namely, foreign imports and domestic production.

Estimates of the quantity of marijuana available in the United States are controversial, and one must necessarily make a number of relatively unverifiable assumptions to calculate the estimated availability of the drug on the market. This brief passage from the Federal Research Division of the Library of Congress explains some of the challenges:

[24] Gettman, Jon. "Consistent, Persistent, Resistant", v
[25] Nisbet and Vakil, 1972, 475

> There is no accepted estimate for marijuana demand in the United States… Marijuana availability has changed little since 2002, according to reporting from law enforcement and public health agencies, as well as federal investigation, arrest, and seizure data. However, availability depends on the state and the type of marijuana. Seizure statistics indicate very limited availability of imported marijuana in a remote state like Alaska but significantly increasing quantities in Texas. It is also important to distinguish between the low-quality, commercial-grade marijuana imported from Mexico and the high-grade product imported from Canada... the [Marijuana Availability Working Group] estimated the street availability of marijuana in 2001 to be between 10,000 and 24,000 pure metric tons. The data reviewed for this survey suggest that the street availability of marijuana is more likely closer to the figure of 24,000 metric tons than it is to 10,000 metric tons.[26]

The range presented in this passage is quite large. One of the greatest challenges, it seems, to estimating the potential tax revenues from a regulated market is that there is "no accepted estimate" for how much is currently being consumed, by how many users, and how that varies with the changing ratio of imports to domestic production, and apparently consistent increases in quality. Another significantly confounding factor in these estimates is that unlike the production of coca or poppy for cocaine and heroin, respectively, marijuana can be grown, and is often grown locally for local consumption.[27] Without more detailed knowledge on domestic production and foreign supply, I utilize many of the same parameters as Gettman, improving them where appropriate. I divide the following estimates into estimates of foreign supply and estimates of domestic production, under the assumption that about half of the market is supplied from each source.[28]

The even split between foreign- and domestic-produced marijuana is perhaps the weakest assumption utilized by my estimates of quantity. The evidence of increased quality of marijuana on the market is commonly attributed to the increased use of hydroponic techniques by indoor, domestic cultivators.

> The ongoing increase in THC levels of the cannabis produced is changing the market. In both Canada and the USA, where large-scale eradication efforts have been successful, the ongoing growth of the THC levels of the cannabis produced is worrying and likely reflects the ongoing shift towards indoor production of high-THC cannabis.[29]

Moreover, the amount of marijuana supplied through import and domestic production, respectively, is almost certainly correlated, at least to some degree, with consumers' preferences for marijuana of varying quality. The Federal Research Division is quick to remind, however, that some governmental estimates suggest that most of the marijuana available to consumers is "smuggled into the United States,"[30] but the boom in domestic production that has taken place over the past five years, particularly in the west, belies this and suggests that potentially more than half of current availability could be produced domestically. Given this considerable uncertainty, an estimate of half-foreign and half-domestic production is reasonable.

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[26] Hudson, Rex. "Marijuana Availability," 1-2
[27] Room et al., Global Cannabis Commission Report, 74.
[28] Hudson, Rex. "Marijuana Availability," 15; 24
[29] World Drug Report 2008, UNODC, 99
[30] Hudson, Rex. "Marijuana Availability," 15

Foreign Imports of Marijuana to the U.S. Market

Nearly all federal seizures of marijuana take place at the borders. Texas ranked first according to a report by the Library of Congress and four states, Texas, Arizona, California and New Mexico, accounted for over 90% of all marijuana seizures in the United States in 2001.[31] The four major sources of import for marijuana to the U.S. market are Mexico, Colombia, Canada and Jamaica.[32] The report also states that "nearly all of Mexico's marijuana production is intended for markets in the United States."[33]

The World Drug Reports from the United Nations Office of Drugs and Crime are also informative on the broader picture of production in North America:

> Close to 60 per cent of global cannabis herb seizures were made in North America… in 2006, notably by the authorities of Mexico (1893 mt), the United States (1139 mt) and, Canada (13 mt). Seizures in North America remained basically stable in 2006… The illicit traffic in cannabis flows mainly from Mexico to the USA and, to a lesser extent, from Canada to the USA. Although much of the marijuana produced in Canada is intended for domestic consumption, cross-border smuggling by organized crime syndicates remains a concern.[34]

Given the clear presence of a large quantity of imported marijuana in the market, it would most likely be appropriate to include some percentage of the marijuana seized in the four dominant source countries: Mexico, Canada, Colombia and Jamaica. In Appendix B I present some of the figures from the State Department's International Narcotics Control Strategy Report (INCSR).

The quantities of marijuana seized, particularly in Mexico, are far from negligible. Over the past seven years, Mexican authorities seized an average of over 1,900 metric tons of marijuana annually. Clearly some fraction of this marijuana, and potentially a very large fraction, was intended for sale in the United States. However, there is absolutely no reliable estimate as to how much of this production was seized, or how successful Mexican authorities are in seizing marijuana. For the sake of creating credible, conservative estimates, I only use data on seizures from U.S. government law enforcement.

To create a ten-year index of quantity seized, I use seizure data from the Sourcebook on Criminal Justice (federal drug-seizure system) and data on seizures from the southwest border. These two sources are largely complementary because the sourcebook data is available for earlier years, whereas the southwest border data comes from the annual National Drug Threat Assessments (NDTA). Where there are observations from both sources for a given year, I take the greater observation. Table 6, below, presents the number of pounds seized between years 1997 and 2007, as reported by the federal-wide drug seizure system and the NDTA reports and a ten-year average quantity of approximately 2.4 million pounds seized.

Domestic Production

Data indicate two primary centers of illicit marijuana production in the United States, namely,

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[31] Hudson, Rex. "Marijuana Availability," 23
[32] ibid.
[33] Hudson, Rex. "Marijuana Availability," 20
[34] World Drug Report 2008, UNODC,102

the west, in California, Oregon and Washington, and the Appalachian region, primarily West Virginia, Kentucky, and Tennessee. As seen in table 6, millions of cultivated marijuana plants are eradicated annually, an increasing number of which are coming from indoor grows and from outdoor grows in national parks. Again, the Federal Research Division report offers important insights:

> Whether cultivated indoors or outdoors, most domestically produced marijuana is intended for sale and use in the local area… Eradication programs and drought conditions in some states have led many growers to abandon outdoor cultivation for indoor sites, which allow growers to better conceal their operations and to control the growing environment… Financial benefits also have encouraged growers to move their operations indoors. Automated systems that can monitor and manipulate conditions in the grow room and advanced growing techniques such as hydroponics have raised not only the quality of the marijuana produced by also the profits derived from its sale. Hydroponic grow operations have been identified in every state and in Puerto Rico… Outdoor cannabis growers often conceal plants… [and] Federal, state and local agencies also continue to identify the widespread use of public lands for cultivation. In 1999 the U.S. Forest Service seized almost 1 million pounds of cannabis plants and processed marijuana in 35 states.[35]

Trends in domestic production are almost impossible to identify, except with regard to the number of plants seized. Table 6, in addition to presenting foreign-sourced, seized marijuana, includes the number of outdoor and indoor plants eradicated in the ten-year period.

Table 6

U.S. Marijuana Seizures and Plant Eradication Data				
Sources: Sourcebook on Criminal Justice Statistics, NDTA 2006-2009; Domestic Cannabis Cultivation Assessment (DCE/SP)				
Seizures in Pounds (2.2 lb =1 kg); Total Plants Eradicated				
Year	**Federal Seizures**	**Southwest Border Seizures**	**Outdoor Plants**	**Indoor Plants**
1997	1,488,362.00		3,827,000.00	224,000.00
1998	1,777,434.00		2,283,000.00	233,000.00
1999	2,282,313.00		3,205,000.00	208,000.00
2000	2,614,746.00		2,597,798.00	217,105.00
2001	2,673,410.00	2,439,038.80	3,068,632.00	236,128.00
2002	2,415,243.00	2,459,138.00	3,128,800.00	213,040.00
2003	2,700,282.00	2,643,033.80	3,427,923.00	223,183.00
2004		2,435,446.20	2,996,144.00	203,896.00
2005		2,272,773.80	3,938,151.00	270,935.00
2006		2,513,440.60	4,830,766.00	400,829.00
2007		3,225,912.80	6,599,599.00	434,728.00
10- year Average		2,403,932.58	3,627,528.45	260,440.36

For both the seizures and the plant eradication data, there are other sources. For instance, the U.S. Forest Service, as I mentioned previously, seizes a good deal of marijuana and eradicates outdoor plants. This data is not included in the plant totals. Turning this data, though, into an

[35] Hudson, Rex. "Marijuana Availability," 12-14

estimate of the quantity available, or supplied, to the U.S. market requires another layer of assumptions, some more verifiable than others.

Foreign Parameter: Seizure Rate

There is no way to know with certainty how much of the foreign marijuana available in the United States is seized in a given year. Moreover, this rate is almost certainly not constant from year to year. Law enforcement can change their patterns of inspection and supply-side actors can change their production and distribution strategy to make up for seized assets. Regardless, there are some indications of what a reliable, if conservative, estimate would be for the seizure rate of imported marijuana.

With regard to foreign sourced marijuana, "there seems to be a general agreement among law enforcement officials that only a maximum of 10 percent of the marijuana being smuggled into the United States is intercepted."[36] In Charleston, inspectors "are able to inspect fewer than 1 percent of the 1.5 million containers that pass through the port annually. The DEA estimates that for every container loaded with illegal drugs discovered at the Charleston port, at least nine other containers with illegal drugs have slipped through without detection."[37] Precisely how the 10% parameter is estimated from this anecdote eludes me.

If inspectors are able to inspect less than 1%, even allowing for them to have some actionable intelligence about which containers to inspect, it is far from clear that they would find a full 10% of the drugs being imported. While this evidence is anecdotal, it should help to reinforce that a seizure rate of 10% with regard to processed, marketable foreign marijuana should be considered an upper bound. In my final estimates, I use a seizure rate of 5% for foreign-sourced marijuana, with minimum and maximum bounds of 2%—slightly greater than that witnessed in Charleston, and 10%—the maximum provided by Hudson in the Federal Research Division report, respectively. Table 7 presents the estimates of foreign-source marijuana supplied to the United States.

Table 7

Estimates of Imported Marijuana		
Seizure Rate	**10-year average, pounds**	**2007, pounds**
2%	120,196,629.09	161,295,640.00
5%	48,078,651.64	64,518,256.00
10%	24,039,325.82	32,259,128.00
	10-year average, grams	**2007, grams**
2%	54,449,072,978.18	73,066,924,920.00
5%	21,779,629,191.27	29,226,769,968.00
10%	10,889,814,595.64	14,613,384,984.00
	10-year average, MT	**2007, MT**
	54,449.1	73,066.9
	21,779.6	29,226.8
	10,889.8[38]	14,613.4

[36] Hudson, Rex. "Marijuana Availability," 23

[37] Hudson, Rex. "Marijuana Availability," 23-24

[38] This figure is almost exactly what the Marijuana Availability Report uses, and doubles, to get "closer to 22,000"

Domestic Parameters

As noted in the passage from the Hudson report above, far less is known about domestic production that foreign imports of marijuana, because the domestic industry has the characteristics of being highly successful, dynamic, and adaptable. They have adapted incredibly well to increased technologies for genetic engineering of different strains and new methods for increasing yield. Rather then simply being able to apply a single rate, there are two necessary parameters for estimating domestic production with this limited data. In addition to applying a plant-eradication rate, similar to the foreign seizure rate, it is necessary to apply an average yield per plant.

Key Parameter: Plant-yield

Estimating the marketable marijuana that one plant will produce, or that the average plant will produce, is similar to trying to estimate how many apples grow on an "average" tree, or how many fish are in an "average" pond. It might be possible to know the answer for a specific type of apple-tree, or for a particular pond at a certain time of year, but it is nearly impossible to answer this question with specificity otherwise. Producers vary. They are not all of the same quality, and do not all have the same resources at their disposal in terms of labor, capital and land. Producers also have to deal with unanticipated variables, particularly if they are growing outdoors, such as bad weather, or pests, and in all growing situations producers have a number of options regarding the application of yield-enhancing technologies and fertilizers.

An anecdote from an article in the New Yorker this past July described a grower who owned "twelve plants" and expected "twenty pounds" of marijuana, depending on the weather.[39] This implies that for these plants, she expected an average of approximately 1.7 pounds per outdoor-grown plant. In indoor grows, with the kinds of technology that can be applied, it is conceivable that some breeds of plants could even generate more than this. Reports in online forums indicate that yields of 1-2 pounds are obtainable under the proper conditions and with experienced growers.[40] [41] [42] [43]

The Domestic Cannabis Eradication and Suppression program of the Federal Drug Enforcement Agency uses a yield of "one pound (448 grams)"[44] in their estimates.[45] Gettman uses estimates of 200 grams and 100 grams for outdoor plants and indoor plants, respectively in his 2006 report[46], but these seem unnecessarily low considering the fact that the DEA estimates greater yields.

Accordingly, I use 300 grams and 200 grams as outdoor and indoor plant yields, respectively, as lower bound estimates. Even with the DEA using higher yields, these can serve as a lower-bound check against crop failure, inexperience or any other reason that a producer would produce below-average yields. As a best guess, I use the DEA's figure of one pound, or 453 grams. As an upper-bound figure, I estimate 1.5 pounds for outdoor plants, and 1.25 pounds for indoor plants,

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[39] Samuels, David "Dr. Kush," *The New Yorker*, July 28, 2008
[40] "Increasing Yield," MarijuanaHydro.com, Wed Apr 1, 2009
[41] "Typical Outdoor Yield," RollItUp.org, accessed Wed Apr 1, 2009
[42] "Typical Plant Yield," Yahoo! Answers, accessed Wed Apr 1, 2009
[43] Conrad, Chris. "Cannabis Garden Adversity," SafeAccessNow.net, Wed Apr 1, 2009
[44] I do not use the conversion of 448 grams per pound but rather 453 grams per pound.
[45] Eradication Estimates, Domestic Cannabis Cultivation Assessment, 2007
[46] Gettman, Jon. "Marijuana Production," 2006

or 680 grams and 567 grams, respectively. This upper bound, moreover, could hypothetically be expected to increase in the move to a legally regulated market, because competition would favor the producers who can generate the greatest yields.

Key Parameter: Plant Eradication Rate

The DEA uses 30%, 40% and 50% plant eradication rates in their estimates of potential, domestically produced marijuana not eradicated every year.[47] Clearly this is very optimistic for a number of reasons. First of all, as evidenced by table 6, the number of plants eradicated every year under the DCE/SP program has increased significantly since 2001. This is consistent across indoor and outdoor operations, as well as operations eradicated on public lands.[48]

Gettman uses a plant-seizure rate of 8% for outdoor-grown and cultivated plants, and a rate of 2% for indoor-cultivation.[49] His 2007 report confirms that allowing for enforcement to seize 40% of the crop is very optimistic:

A 1982 report by DEA, for example, indicated that in most states eradication efforts seized 10 to 20% of the marijuana grown there. A 1994 report by ONDCP suggested that marijuana eradication programs on average eradicated 20% of all marijuana grown in the US.[50]

Combined with the Marijuana Availability report estimate that only 10% of drugs "reaching the market" are seized upon import, I use the DEA estimate of a 30% plant eradication rate to yield a minimum quantity of domestically cultivated marijuana. The idea that law enforcement are seizing a full 30% of the domestically produced marijuana reaching the market is somewhat farcical, but as a possible seizure rate suggested in the DEA data, it can still serve as a conservative, upper-bound eradication rate.

I use more reasonable estimates of 8% and 5% for outdoor and indoor plants, respectively, as a best guess. As a minimum seizure rate (which yields the maximum domestic production), I use 5% and 2% for outdoor and indoor plants, respectively.

Tables 8 and 9 present my estimates of outdoor- and indoor-grown marijuana, respectively.

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[47] Eradication Estimates, Domestic Cannabis Cultivation Assessment
[48] National Drug Threat Assessment 2009
[49] Gettman, Jon. "Marijuana Production," 2006, 7
[50] Gettman, Jon. "Lost Taxes", 2007, 28

Table 8

Outdoor Cultivation Estimate			
Quantities in Grams			
Yield	**Seizure Rate**	**10-year Average Quantity**	**2007 Quantity**
680	5%	49,334,386,982	89,754,546,400
453	8%	20,540,879,874	37,370,229,338
453	10%	16,432,703,899	29,896,183,470
300	5%	21,765,170,727	39,597,594,000
300	8%	13,603,231,705	24,748,496,250
300	10%	10,882,585,364	19,798,797,000
300	30%	3,627,528,455	6,599,599,000

Table 9

Indoor Cultivation Estimate			
Quantities in Grams			
Yield	**Seizure Rate**	**10-Year Average Quantity**	**2007 Quantity**
567	2%	7,383,484,309	12,324,538,800
453	5%	2,359,589,695	3,938,635,680
453	8%	1,474,743,559	2,461,647,300
200	2%	2,604,403,636	4,347,280,000
200	5%	1,041,761,455	1,738,912,000
200	8%	651,100,909	1,086,820,000
200	30%	173,626,909	289,818,667

Table 10 presents total domestic cultivation estimates for the range of parameters employed in tables 8 and 9.

Table 10

Total Domestic Cultivation					
Quantities in Grams					
Outdoor Yield	**Eradication Rate**	**Indoor Yield**	**Eradication Rate**	**10-year Average**	**2007 Quantity**
680	5%	567	2%	56,717,871,291	102,079,085,200
453	8%	453	5%	22,900,469,568	41,308,865,018
453	10%	453	8%	17,907,447,458	32,357,830,770
300	5%	200	2%	24,369,574,364	43,944,874,000
300	8%	200	5%	14,644,993,159	26,487,408,250
300	10%	200	8%	11,533,686,273	20,885,617,000
300	30%	200	30%	3,801,155,364	6,889,417,667

Combining the domestic production estimate from Table 10 with the foreign-sourced marijuana estimate from Table 7, Table 11 presents my overall estimates of the supply, or quantity of marijuana consumed in the United States.

Table 11

Estimates of Total Quantity in the Current Market (Q_0)				
	Outdoor, Indoor	**Outdoor, Indoor**		
Seizure Rate	**Yield**	**Eradication Rate**		
Best-Guess Estimate				
8%	453	8%, 5%	**10-year Average**	**2007**
		Grams	44,680,098,760	70,535,634,986
		Metric Tons	44,680.1	70,535.6
Minimum Quantity				
10%	300, 200	30%	**10-year Average**	**2007**
		Grams	14,690,969,959	21,502,802,651
		Metric Tons	14,691.0	21,502.8
Maximum Quantity				
5%	680, 567	5%, 2%	**10-year Average**	**2007**
		Grams	111,166,944,269	175,146,010,120
		Metric Tons	111,166.9	175,146.0

The range of this estimate is extremely wide. By nature of the data available, there is a considerable amount of uncertainty involved and so the potential range of quantity is necessarily large. Here, quantity ranges from 14,691 metric tons, which is approximately the average quantity that Gettman uses, to an astonishing 175,146 metric tons, taking the more liberal parameters and the most recent data.

Section 6: Final Estimates of Quantity (Q_2) and Potential Tax Revenue

Having presented my estimates for the necessary variables P_0, P_1, Q_0 and ε_D, recall equation 3 from section 2:

$$(3)\ [\varepsilon_D * [(P_2-P_0)/P_0]]*Q_0 + Q_0 = Q_2$$

Additionally, recall that P_2 is defined as our estimated P_1 plus whatever tax rate is applied.

For a unit tax, I expressed this in equation 4:

$$(4)\ P_2 = P_1 + \tau$$

And, in the case of an ad-valorem tax:

$$(5)\ P_2 = P_1 (1+ \tau)$$

Our variable of interest is still R, revenue from equation 1:

$$(1)\ R = \tau * Q_2$$

But in order to find R, we first must apply a unit tax or an ad-valorem tax to create P_2.

With a unit tax, then, we can substitute equation 4 into equation 3 to estimate Q_2:

$$(6)\ [\varepsilon_D * [((P_1+\tau)-P_0)/P_0]]*Q_0 + Q_0 = Q_2$$

And with an ad-valorem tax, substituting equation 5 into equation 3 provides an estimate of Q_2:

$$(7)\ [\varepsilon_D * [((P_1\tau+P_1)-P_0)/P_0]]*Q_0 + Q_0 = Q_2$$

In these equations, Q_2 will be greater than Q_0 as long as the final values for P_2 are less than our initial, illegal market equilibrium price P_0.

At this point, policy makers are faced with the challenging task of setting a tax per unit, or a tax rate, based on wide-ranging potential estimates of the pertinent variables. It is necessary, then, to discuss briefly what an optimal tax would accomplish.

Optimal Taxation

The optimal tax rate for an excise tax of this nature, or a sin tax, is a rate which accomplishes multiple, often conflicting, goals. First, a tax of this nature must be designed to minimize the harms to society from use of the drug, typically by reducing consumption to a certain level. Also important, however, is attempting to ensure compliance and maximize tax revenue. The tax and regulate bill recently introduced in Massachusetts recognized this, stating that:

> Such excise shall be adjusted from the authority from time to time as necessary to maximize the

> revenue derived therefrom, and to minimize the incentive for the sale of cannabis not in accordance with this act.[1]

These conflicting goals are often represented in the debate over cigarette tax rates and cigarette tax compliance. Policy makers want to maximize the revenue generated from the sale of cigarettes because it helps to offset the externalities that consumption of cigarettes imposes on society. But even with perfect compliance, higher taxes means reduced consumption, and eventually revenue will start to decrease as consumption does, even as the tax rate increases.

This is, effectively, a typical discussion of the effects of the Laffer curve. The Laffer curve can be applied to any tax, and is most-often represented by a typical bell-curve. On the left side of the bell, as the tax rate increases, revenue increases. But as the tax rate continues to increase beyond some optimal level of taxation, τ^*, that balances the ideal consumption (or in the case of an income tax, hours worked) and revenue, tax revenue will decrease as consumers cease to consume the good or start to substitute away from hours worked to consumption of, say, leisure.

Simultaneously, the higher the tax rate, the higher the incentive is for consumers to find a means of tax avoidance or evasion. In section 3 I discussed incentives for compliance, on both the supply-side and the demand-side, at length. If supply shifts outward as expected, and the after-tax price still falls from its current state, there is little reason to believe that widespread non-compliance would be likely. Still, the case of cigarettes does show that there is some degree of non-compliance currently. Stehr estimates that tax avoidance accounted for up to 9.6% of cigarette sales between 1985 and 2001.[2] With the increase in Internet usage, Goolsbee also argues that smoking has become less sensitive to tax rates because there are other means of obtaining low- or no-tax cigarettes online.[3]

In the situation of a legally taxed and regulated marijuana market, then, the optimal tax is one that allows price to fall somewhat, so as to maximize compliance as per my discussion from section 3, while minimizing the change in quantity that occurs due to legally regulating the market, and generating as much revenue as possible. In other words, the optimal tax is one that sets τ^* such that P_2 is only slightly lower than P_0.

In order to show the revenue that would result from setting $P_2 = P_0$, I solve equations 6 and 7 for τ such that $Q_2 = Q_0$. The optimal tax, τ^*, is given by equation 8 for a unit tax:

$$(8)\ P_0 - P_1 = \tau^*$$

Or equation 0 for an ad-valorem tax:

$$(9)\ (P_0 - P_1)/P_1 = \tau^*$$

Importantly, if the tax is set as a level $\tau > \tau^*$, we expect non-compliance at a far greater rate than we would at $\tau < \tau^*$, particularly in the short-run as the market transitions to a legally regulated

[1] Mass. Senate No. 1801, Filed 1/16/2009
[2] Stehr, (2004), 277
[3] Goolsbee, 2004

equilibrium. In the longer run, the Becker analysis of optimal tax enforcement might hold, and policy makers might be able to set the tax such that $\tau > \tau^*$, but to maximize the chance of a successful transition, in terms of compliance, to a legally regulated market, I assume that $\tau < \tau^*$ will occur.

Accordingly, to estimate tax revenue, our variable of interest, rather than simply estimating $\tau * Q_2$, I estimate an expected tax revenue that is equal to $90\% * \tau * Q_2$, if $\tau < \tau^*$ or $\tau = \tau^*$, under the assumption that similar to the market for cigarettes, tax avoidance and evasion could account for up to 10% of sales. For $\tau > \tau^*$, I set expected revenue equal to $50\% * \tau * Q_2$.

Table 12 and table 13 present my estimates of Q_2 and expected tax revenue for a range of unit taxes and ad-valorem taxes, respectively.

Table 12

Unit Tax Rates & Final Estimates					
Unit Tax		**Estimate of Q2**	**Implied Ad-Valorem (%)**	**Expected Tax Revenue**	**100% Compliance**
Best-guess Range: P_0 = \$11.12, P_1 = \$3.05, Q_0 = 44,680,098,760 g, ε_D = -0.857					
	\$2.00	65,593,359,989	65.6%	\$118,068,047,980	\$131,186,719,978
	\$3.00	62,150,173,687	98.4%	\$167,805,468,955	\$186,450,521,061
	\$4.00	58,706,987,385	131.2%	\$211,345,154,588	\$234,827,949,542
	\$5.00	55,263,801,084	164.0%	\$248,687,104,877	\$276,319,005,419
	\$6.00	51,820,614,782	196.8%	\$279,831,319,824	\$310,923,688,693
	\$7.00	48,377,428,481	229.6%	\$304,777,799,427	\$338,641,999,364
τ*	**\$8.07**	44,680,098,760	264.8%	\$324,664,786,819	\$360,738,652,021
Minimum Range: P_0 = \$11.12, P_1 = \$1.52, Q_0 = 14,690,969,959 g, ε_D = -0.720					
	\$2.00	21,916,873,388	131.2%	\$39,450,372,098	\$43,833,746,776
	\$3.00	20,965,882,941	196.8%	\$56,607,883,942	\$62,897,648,824
	\$4.00	20,014,892,495	262.4%	\$72,053,612,981	\$80,059,569,978
	\$5.00	19,063,902,048	328.0%	\$85,787,559,216	\$95,319,510,240
	\$6.00	18,112,911,601	393.6%	\$97,809,722,646	\$108,677,469,607
	\$7.00	17,161,921,154	459.2%	\$108,120,103,273	\$120,133,448,081
τ*	**\$9.60**	14,690,969,959	629.6%	\$126,907,402,014	\$141,008,224,460
Maximum Range: P_0 = \$11.12, P_1 = \$7.23, Q_0 = 111,166,944,269 g, ε_D = -0.994					
	\$2.00	129,978,469,291	27.7%	\$233,961,244,724	\$259,956,938,582
	\$3.00	120,040,902,634	41.5%	\$324,110,437,113	\$360,122,707,903
	\$4.00	110,103,335,978	55.3%	\$220,206,671,955	\$440,413,343,910
	\$5.00	100,165,769,321	69.2%	\$250,414,423,302	\$500,828,846,604
	\$6.00	90,228,202,664	83.0%	\$270,684,607,992	\$541,369,215,984

	$7.00	80,290,636,007	96.8%	$281,017,226,025	$562,034,452,050
τ*	**$3.89**	111,166,944,269	53.8%	$389,492,716,448	$432,769,684,942
Mid-point Range 1: P_0 = $11.12, P_1 = $2.29, Q_0 = 29,685,534,359 g, ε_D = -0.789					
	$2.00	44,073,003,915	87.5%	$79,331,407,047.00	$88,146,007,830.00
	$3.00	41,968,357,734	131.2%	$113,314,565,880.50	$125,905,073,200.56
	$4.00	39,863,711,552	174.9%	$143,509,361,587.34	$159,454,846,208.16
	$5.00	37,759,065,371	218.7%	$169,915,794,167.53	$188,795,326,852.81
	$6.00	35,654,419,189	262.4%	$192,533,863,621.05	$213,926,515,134.50
	$7.00	33,549,773,008	306.1%	$211,363,569,947.90	$234,848,411,053.23
τ*	**$8.84**	29,685,534,359	386.4%	$236,072,617,710.16	$262,302,908,566.85
Mid-point Range 2: P_0 = $11.12, P_1 = $5.14, Q_0 = 77,923,521,514 g, ε_D = -0.926					
	$2.00	103,757,520,232	38.9%	$186,763,536,416.91	$207,515,040,463.23
	$3.00	97,272,091,013	58.4%	$262,634,645,734.11	$291,816,273,037.90
	$4.00	90,786,661,794	77.8%	$326,831,982,457.13	$363,146,647,174.59
	$5.00	84,301,232,575	97.3%	$379,355,546,585.98	$421,506,162,873.31
	$6.00	77,815,803,356	116.7%	$233,447,410,067.03	$466,894,820,134.07
	$7.00	71,330,374,137	136.2%	$249,656,309,478.43	$499,312,618,956.85
τ*	**$5.98**	77,923,521,514	116.4%	$419,622,189,583.06	$466,246,877,314.51

Table 13

Ad-valorem Tax Rates - Final Estimates					
Tax Rate		**Estimate of Q2**	**Implied Unit Tax ($/g)**	**Expected Tax Revenue**	**100% Compliance**
Best-guess Range: P_0 = $11.12, P_1 = $3.05, Q_0 = 44,680,098,760 g, ε_D = -0.857					
	30%	69,330,287,664	$0.91	$57,074,091,649	$63,415,657,387.88
	40%	68,280,472,688	$1.22	$74,946,483,706	$83,273,870,784.13
	50%	67,230,657,712	$1.52	$92,242,723,182	$102,491,914,647.19
	60%	66,180,842,736	$1.83	$108,962,810,079	$121,069,788,977.06
	70%	65,131,027,761	$2.13	$125,106,744,396	$139,007,493,773.75
	80%	64,081,212,785	$2.44	$140,674,526,134	$156,305,029,037.24
	90%	63,031,397,809	$2.74	$155,666,155,291	$172,962,394,767.55
τ*	**265%**	44,680,098,760	$8.07	$324,664,786,819	$360,738,652,020.84
Minimum Range: P_0 = $11.12, P_1 = $1.52, Q_0 = 14,690,969,959 g, ε_D = -0.720					
	30%	23,383,923,991	$0.46	$9,625,059,018	$10,694,510,019.61

	40%	23,238,947,227	$0.61	$12,753,846,826	$14,170,940,917.31
	50%	23,093,970,463	$0.76	$15,842,852,035	$17,603,168,927.28
	60%	22,948,993,700	$0.91	$18,892,074,645	$20,991,194,049.49
	70%	22,804,016,936	$1.07	$21,901,514,656	$24,335,016,283.96
	80%	22,659,040,173	$1.22	$24,871,172,068	$27,634,635,630.68
	90%	22,514,063,409	$1.37	$27,801,046,881	$30,890,052,089.65
τ*	**630%**	14,690,969,959	$9.60	$126,907,402,014	$141,008,224,460.33
Maximum Range: P_0 = $11.12, P_1 = $7.23, Q_0 = 111,166,944,269 g, ε_D = -0.994					
	30%	128,299,607,246	$2.17	$250,446,845,905	$278,274,273,227.65
	40%	121,114,942,127	$2.89	$315,229,390,525	$350,254,878,360.90
	50%	113,930,277,007	$3.61	$370,662,066,471	$411,846,740,522.84
	60%	106,745,611,888	$4.34	$231,524,929,857	$463,049,859,713.47
	70%	99,560,946,768	$5.06	$251,932,117,966	$503,864,235,932.78
	80%	92,376,281,649	$5.78	$267,144,934,590	$534,289,869,180.78
	90%	85,191,616,529	$6.51	$277,163,379,729	$554,326,759,457.46
τ*	**54%**	111,166,944,269	$3.89	$389,492,716,448	$432,769,684,941.88
Mid-point Range 1: P_0 = $11.12, P_1 = $2.29, Q_0 = 29,685,534,359 g, ε_D = -0.789					
	30%	46,838,473,610	$0.69	$28,918,782,385	$32,131,980,427.89
	40%	46,357,199,388	$0.91	$38,162,181,863	$42,402,424,292.29
	50%	45,875,925,165	$1.14	$47,207,484,016	$52,452,760,017.57
	60%	45,394,650,943	$1.37	$56,054,688,843	$62,282,987,603.74
	70%	44,913,376,720	$1.60	$64,703,796,346	$71,893,107,050.79
	80%	44,432,102,498	$1.83	$73,154,806,523	$81,283,118,358.73
	90%	43,950,828,275	$2.06	$81,407,719,375	$90,453,021,527.56
τ*	**386%**	29,685,534,359	$8.84	$236,072,617,710	$262,302,908,566.85
Mid-point Range 2: P_0 = $11.12, P_1 = $5.14, Q_0 = 77,923,521,514 g, ε_D = -0.926					
	30%	106,729,046,474	$1.54	$148,100,802,443	$164,556,447,158.84
	40%	103,395,935,743	$2.06	$191,300,888,354	$212,556,542,616.00
	50%	100,062,825,011	$2.57	$231,417,550,148	$257,130,611,275.26
	60%	96,729,714,279	$3.08	$268,450,787,823	$298,278,653,136.64
	70%	93,396,603,547	$3.60	$302,400,601,380	$336,000,668,200.12
	80%	90,063,492,816	$4.11	$333,266,990,819	$370,296,656,465.71
	90%	86,730,382,084	$4.63	$361,049,956,140	$401,166,617,933.40
τ*	**116%**	77,923,521,514	$5.98	$419,622,189,583	$466,246,877,314.51

In addition to presenting best guess, minimum and maximum range estimates, I also create two mid-point estimates. Mid-point Range 1 estimates the tax revenue that would result if the true

value of each of the input variables were the average of my best-guess and minimum-range estimates. Mid-point Range 2 estimates the same thing, respectively, for my best-guess and maximum-range estimates. The far right column of each range is a 100% compliance rate, or the result of $\tau * Q_2$. This serves as a comparison to the expected tax revenue, which is conditional upon whether τ is less than, equal to, or greater than τ^* as discussed above.

Tables 12 and 13 present estimates of tax revenue based on the 10-year average quantity estimates. Estimates of tax revenue based on the 2007 quantity figures can be found in Appendix C.

With regard to setting the optimal tax, $\boldsymbol{\tau^*}$ is highly dependent on P_1, the pre-tax regulated price of marijuana. The range of $\boldsymbol{\tau^*}$ goes from 54%, or approximately $3.89 per gram, when P_1 is high, at $7.23 per gram, to a very large 630%, or approximately $9.60 per gram, when P_1 is low at $1.52 per gram. This presents a challenge to policy makers in terms of setting the appropriate tax. Due to the inherent uncertainty of the estimates for P_1, it would behoove policy makers to set a unit tax rather then an ad-valorem tax.

A tax of $4 per gram, or approximately $112 per ounce, is less than $\boldsymbol{\tau^*}$ for all ranges above, with the exception of the maximum range. For some of the ranges, this tax is less than optimal – that is, price could still fall considerably. But as I have argued, it is ideal for price to fall in the short term, so that one could expect reasonable compliance rates in the long-run.

Accordingly, if federal policy makers legally taxed and regulated marijuana, with an excise tax of $4 per gram, I predict that this would generate at least $72.1 billion annually, under the most minimal of circumstances. Under my best-guess estimate, this tax would generate approximately $211.3 billion, and under more optimistic assumptions (at least with respect to revenue) could generate over $300 billion annually in excise tax revenue.

Importantly, remember that these figures are still likely to understate the tax revenue, because the assumption of perfect elasticity of supply in the long run means that producers will bear no part of the tax. If producers do bear some of the tax burden—if supply is not perfectly elastic—then quantity will rise by a greater amount from Q_0 to Q_2 than it does in my estimates presented above.

Comparable Budgetary Effects

No other goods generate this much money in tax revenue. Federal excise tax receipts for fiscal year 2008, according the President Obama's fiscal year 2010 Budget, are only $67 billion.[4] Even if *only* my minimal range holds and *only* $72.1 billion is generated, federal excise tax revenue would increase 107%.

In comparison to other federal program areas, my estimates suggest that legally taxing and regulating marijuana could potentially pay for Medicaid. In FY 2008 Medicaid was projected to cost $201 billion—$10.2 billion less then my best guess. The $211 billion figure is also $17.3

[4] FY 2010 budget, table S-3

billion greater then 2008 Medicare tax receipts.[5] Reports frequently cite the cost of the War in Iraq at $10 to $12 billion.[6] President Obama used the estimate of $10 billion a month in Iraq multiple times throughout the campaign, including in a popular fall television ad.[7] Using this $10 billion base line, the $211 billion I estimate as a best guess could fund over twenty months in Iraq.

The finding that there is potentially as much $211 billion annually to be generated in a legally taxed and regulated marijuana market has ground-breaking implications for improving the long-term prospects of the federal deficit and debt, and as I have consistently argued throughout this report, this figure of $211 billion could still be underestimated.

Comparison to the Literature

Perhaps more important than understanding the enormity of my estimates, it is critical to understand why they differ so greatly from the literature. Miron generates his 2005 estimate of $6.2 billion not through a full supply and demand model, as I do, but does so by taking the 2002 ONDCP figure of $10.5 billion in "expenditure," annually.[8] It is not surprising, then, that my estimates vary significantly from his because I have estimated a market equilibrium model much different then the figures that Miron uses. Boyd, in his estimate for Hawaii, effectively sticks to the Miron framework.

Gettman undertakes a market analysis far more similar to mine. While his estimate is conservative, and finds that a taxed marijuana market could generate $31.1 billion in tax revenue annually, Gettman does not attempt to account for how the market equilibrium would change under legally taxed and regulated conditions. As I have argued throughout this report, Gettman's analysis suffers from a number of other flaws as well.

For instance, in estimating price, Gettman used data for the price range of 10 to 100 grams, whereas a price estimate for the less-than-10 gram quantity level is more appropriate to the expected conditions in a legally regulated market. Another significant difference from Gettman is that I do not include demand-side estimates of quantity on the market. This naturally biases my estimate upward from his, but as I have argued, demand-side estimates are known to consistently and systematically underreport the number of marijuana users and the characteristics of their use, and the most recent NSDUH data on number of joints per user per day is over fifteen years old. Gettman's final result of $31.1 billion is obviously lower then mine, but as I have argued, should be seen as an underestimate.

In the next section, I discuss a number of other factors that could alter significantly the budgetary calculus of a shift to a legally regulated market.

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[5] ibid.
[6] MSNBC page
[7] New Obama Ad, CNN
[8] Miron, 2005, 17

Section 7: Related Economic Effects and Areas for Further Research

The potential budgetary impact of taxing and regulating marijuana is far broader and more profound then the potential tax revenue that could be generated. The scope of such a policy decision, even in strictly economic terms, is extremely wide-ranging. In this section, I will attempt to address some of the diverse economic impacts that such a change in policy could catalyze. While these areas are largely beyond the scope of this report, I believe significant budgetary savings, as well as improvements in welfare, could result in these areas from the transition to a legally taxed and regulated marijuana market.

Effects on Health

Perhaps the most important issue in determining the ultimate costs and benefits of marijuana regulation is determining the impact on public health. Any legitimate policy alternative will necessarily discuss the broader ramifications of marijuana consumption for physical and psychological health of users. Room explains that "research over the past decade has provided evidence that [cannabis] can have adverse effects on some users,"[1] and explores such issues as the increased risk of car accidents, the effects of a cannabis dependence syndrome, the respiratory and cardiovascular effects and the effect on cognitive performance and brain function.

Each of these effects has been associated with cannabis use in the medical literature, but the overall public health burden has not, in my opinion, been shown conclusively to be worse then that of alcohol or tobacco. Room summarizes the comparative literature, explaining that cannabis was in the lowest risk-group for a fatal overdose, was less intoxicating than alcohol, cocaine or heroin, was placed at the lowest level of addictiveness or dependence and generally was weak on other measures of "social dangerousness."[2]

The finding, simply, that some substance causes harm is not enough to prohibit such a substance. Where the harm has been found to be great, as in the case of tobacco, tax policy has adapted to charge increasingly higher taxes on cigarettes. Recall, now, that from the standpoint of traditional economic theory, we should not be concerned with the harm that individual marijuana users inflict upon themselves, per se, except insofar as it creates negative societal externalities. But the literature largely suggests that the tax on cigarettes is high enough to pay for most, if not all of the externalities generated by the consumption of cigarettes. Manning et al., attempted to determine "whether smokers paid their way" in their seminal 1989 report:

> We estimate the lifetime, discounted costs that smokers and drinkers impose on others through collectively financed health insurance, pensions, disability insurance, group life insurance, fires, motor-vehicle accidents, and the criminal justice system. Although nonsmokers subsidize smokers' medical care and group life insurance, smokers subsidize nonsmokers' pensions and nursing home payments. On balance, smokers probably pay their way at the current level of excise taxes on cigarettes; but one may, nonetheless, wish to raise those taxes to reduce the number of adolescent smokers. In contrast, drinkers do not pay their way: current excise taxes on alcohol cover only about half the costs imposed on others.[3]

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[1] Room et al., Global Cannabis Commission Report, 21
[2] Room et al., Global Cannabis Commission Report, 52-54
[3] Manning et al., 1989

An earlier paper by Shoven et al. looks at the viability of social security, and finds that "every decrease in the number of smokers in society increases the [social security] system's liability.[4] Gruber reminds us that these costs are not uncontroversial, because there are several reasons why the Manning estimate of costs imposed is an underestimate:

> The first is the health costs of secondhand smoke, arising through increased risk of lung cancer and (even more importantly) cardiac disease. The size of such costs is quite ambiguous and controversial… A second issue involves pregnant women. Smoking leads to an increased incidence of low-birth-weight babies, which imposes both short-run costs of medical care and long-run costs of special education. [5]

The literature on optimal taxation for cigarettes is far from conclusive. But ultimately, the debate is about how to minimize the societal costs imposed by cigarettes through taxation. With marijuana, prohibition prevents this debate. In turn, we are not concerned with the costs of marijuana use in terms of health, per se, but only insofar as these costs might increase beyond their current level.

If quantity consumed increases, whatever costs are imposed on society from cannabis use could be exacerbated. The critical assumption made in section 2—that demand would not shift in the long term—could cause a greater quantity of consumption, but it would also cause greater revenues that could help to offset the additional costs of marijuana use. Further health costs could be imposed by the complementary nature of marijuana and tobacco. If the decrease in price causes higher consumption of cigarettes, for instance, the long-term health costs associated with cigarettes, such as second-hand smoke and effects on pregnant women, which are hardest to quantify, could increase.

If the change in policy encourages youth smoking, moreover, this could complicate the effects of health cost estimates. If young marijuana users are more likely to become dependent on marijuana in a legally regulated marijuana market, the lifetime costs of their use could increase, but this would again potentially be offset, at least to some degree, by the revenue generated. Youth access to marijuana, however, is not likely to change considerably. Marijuana is most often acquired through social sources, as are tobacco and alcohol, which despite being illegal for underage users, are consumed by youth. The impact on youth, and specifically the health impact therein also require further research.

Some health-related costs could fall with the change in policy, however. If prescription drug companies are forced to compete with medicinal marijuana, for example, prices could fall. This could have a huge impact on reducing long-term health care entitlement spending, specifically the Medicare D prescription drug program.

Ultimately, far more research must be conducted on the health effects of marijuana use, both in terms of acute and long-term use. This research should assess the externalities imposed on society through marijuana use, as well as any personal costs that may not be internalized. At present, however, the costs of use are still borne by society without any revenue to compensate.

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[4] Shoven et al., 1987
[5] Gruber, 2002, 152

Effects on Criminal Justice and Drug Enforcement Costs

The effects of ending prohibition on the criminal justice system, and the savings or reduced costs involved with these effects have been more extensively studied than potential tax revenues, as I mentioned in section 1. This area of savings and reduced costs merits further research, but there is no reason to believe that removing prohibition would exact more costs than prohibition in terms of criminal justice and enforcement.

First, as Miron and others have estimated, there could be billions of dollars in savings at the state and local level due to having fewer people incarcerated. Next, however, with regards to incarceration, there are a lot of "hidden" costs that are not typically included in estimates of the savings from the removal of prohibition. These costs include reduced wages, lifetime earnings and reduced child support payments. Kleykamp estimates that these costs "could run 70 to 150 percent higher than direct state expenditures on incarceration" for New Jersey.[6] There could also be a significant societal benefit from expending law enforcement resources currently used against marijuana against violent crimes, like murder or rape, or against harder drugs. A reduction in the murder rate could have a tremendous economic impact on society. Finally, legal regulation would prevent such a massive source of wealth and production from funding other criminal activities.

The impact of such a change in policy on the criminal justice system is vast and merits further exploration. For the purposes of this report, however, suffice to say that the exclusion of these savings should only bias my estimate of the budgetary impact of taxing and legally regulating marijuana downward.

Effects on International Relations

As I discussed briefly in section 1, the current international legal status of marijuana, and cannabis generally, makes it challenging to know what legal options the federal government would even have to legally tax and regulated marijuana. That said, there could be significant global economic effects. For instance, actions by the United States could start a chain effect, whereby other nations quickly remove the prohibition of cannabis products. As one of the largest market shares for consumption, the imposition of an import tariff or quota could strengthen the domestic marijuana cultivation industry.

Much of the current violence in Mexico could potentially be eliminated with such a change in policy. International trade could flourish as many developing countries might choose to grow marijuana for export. This might not even threaten domestic producers, as American producers have access to significantly greater amounts of capital to utilize technologically enhanced cultivation than do potential marijuana farmers in developing countries.

Very little research has been done on the extent of how globalization would or could potentially interact with such a change in U.S. domestic policy, and clearly these effects merit further research as well. Ultimately, these considerations should both factor into an estimate of the budgetary impact and help to frame the regulatory approach taken by policymakers.

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[6] Kleykamp, "Wasting Lives," 2

Effects on the Labor Market, Spin-off Industries and Economic Stimulus

A final area of related economic effects that would be catalyzed by the shift to a legally regulated marijuana market are those relating to labor, spin-off industries and economic stimulus.

The labor market effects of illicit drug use have been studied to some degree in the economics literature. Register and Williams examined the labor market effects of drug use, specifically marijuana and cocaine, on productivity, as measured by wages, in 1992. They found "that although long-term and on-the-job use of marijuana negatively affected wages, the net productivity effect for all marijuana users (both those who engaged in long-term or on-the-job use and those who did not) was positive."[7] Desimone, conversely, uses an instrumental variables approach to estimating the impact of drug use on employment, and finds that marijuana use reduces the likelihood of employment.[8] Buchmueller and Zuvekas control for different age groups and intensity of drug use, and find that these differences are significant.[9]

While there is no consensus on how increased use might effect productivity, wages, or employment, however, the change to a legally regulated marijuana market would have various other significant effects on the labor market and on spin-off industries.

First of all, the change in policy would undoubtedly create jobs at retail dispensaries and new firms would enter the supply market, creating opportunities for employment along the entire supply chain. The jobs that already exist, moreover, could be counted as legitimate jobs, inflating the number of jobs that could be claimed as "created" even further. Moreover, firms that produce the best marijuana—the most competitive firms—will require a relatively labor-intensive growing process to do so. Technicians will be required to manage the aeration systems, nutrients and other inputs into successful marijuana cultivation.

Spin-off industries would flourish. Hemp, for example, could become a major agricultural staple in addition to marijuana, creating even more jobs and generating higher levels of productivity. Other cannabis products could flourish as well, such as hashish or baked goods made with cannabis oil or butter. These auxiliary cannabis products are not included in my estimates of tax revenue, nor do I make any calculation for industrial hemp, but certainly these effects should be significant. Other industries could see growth from the change in policy as well. International interest could generate some degree of tourism to certain key cities as it does for Amsterdam in the Netherlands. This has arguably already occurred to some degree in northern California, which has become known for its high-quality marijuana due to the boom in medical marijuana in the past decade or so. The fast food industry could even see a boom as a greater number of people "get the munchies" and order pizza for delivery, or eat more Tostitos.

All of these areas require further research as many of them represent significant opportunities to catalyze growth and stimulate the economy. Unfortunately, for now they are outside the scope of my estimates.

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[7] Register and Williams, 1992, 435
[8] Desimone, 2002
[9] Buchmueller and Zuvekas, 1998

Section 8: Conclusion

In this report, I have estimated the potential revenue that could be generated from the shift to a legally regulated marijuana market. I first discuss the context—historically, politically, and with regard to the current literature. I discuss the theoretical effects of such a change in policy at length, and using this background, I utilize standard overarching estimation techniques. I discussed the range of policies that could be enacted, with an eye towards maximizing compliance and revenue, minimizing harm. I then estimate current and potential figures for several key variables, including price, quantity and the elasticity of demand. Finally, I apply hypothetical tax rates, for both ad-valorem and unit taxes. I conclude, finally, that at minimum $72.1 billion in tax revenue could be generated annually, with a more accurate estimate of $211 billion yielding a best guess, and some more optimistic estimates (from the standpoint of generating revenue) upwards of $300 billion.

My report suffers from a number of limitations. As with the vast majority of the literature in the field of drug use economics, the available data is extremely limited, and none of the data is even remotely perfect. One of the precise reasons that my estimates differ so greatly from Gettman, for instance, is simply that I chose to exclude a data source in my quantity estimate. I believe that this exclusion was justified by the data, and that it serves to make my final estimates more credible. Regardless, the limitations of the data are challenging, especially given the requirement of having estimates for so many variables.

Because my variable of interest was revenue, moreover, the statistical techniques available to me even with the given data are not precise techniques. With better data sets it might be possible to create far more sophisticated estimates of price or quantity in the current market. For instance, good data on the characteristics of use, frequency of use, the number of marijuana users in the country and their characteristics, the response to increases in quality, and so on, could be used generate sophisticated demand side-estimates of quantity. This data is simply not available. Similarly on the supply side, better data on costs of technology and price premiums for higher quality products, as well as the structure of the distribution chain for marijuana currently, could lead to a far better understanding of the optimal regulation structure for a new market, the costs that regulation will impose on producers, and in turn optimal tax rates.

A final limitation, or potential objection, might be simply that a great deal of the speculation required to finalize my estimates is necessarily hypothetical. This is certainly true, but that is simply a reflection of the fact that the very variable of interest is hypothetical! Still, having some sense of what the opportunity cost of prohibition is in terms of excise tax revenue is absolutely essential to discussing the merits and demerits of marijuana prohibition.

Despite these limitations, my estimates are innovative in a number of ways. I have added to the framework established by authors such as Gettman and Miron, updating the model for understanding the impact of such a policy change on potential tax revenue. Unlike Gettman, I estimate elasticity and attempt to impose hypothetical tax and regulated conditions on a revised estimate of the current market equilibrium. Additionally, I undertake a more in-depth analysis of the theoretical effects, as well as the various policy contexts, than other recent estimates of tax revenue.

As further research is conducted and new policies are implemented, the validity of these estimates will be challenged. Hopefully, new and improved data will lead to better economic projections of the tax revenues and macroeconomic impacts of legally taxing and regulating marijuana. Still, in light of the current political and economic climate, my estimates are highly relevant to the policy debate.

The political dynamic with regard to marijuana is changing, and it is changing quickly. In the past several weeks, new articles and blog posts about this very topic have been posted almost daily. Andrew Sullivan's *The Daily Dish*, a blog that I frequently read, has featured a recurring post of readers' stories about their own marijuana use, coming out of the "cannabis closet."[1] These posts, the stir-up over President Obama's internet town hall meeting, the letters and editorials in papers around the country[2]—in my opinion, these are all both catalysts of this changing political dynamic, as well as evidence thereof.

I recently had the chance to hear former Senator John Edwards speak, and had the further opportunity to ask him a question about whether the current economic situation could be seen as an opportunity to give consideration to legalizing marijuana. His answer, in short, was that it might be time to "take some risks," politically.

I strongly doubt that the Obama administration will take the political risks that will be required to jumpstart serious dialogue about ending marijuana prohibition at the federal level, and transitioning to a legally taxed and regulated marijuana market. He has consistently said he would not do so. But the available data suggests that the benefit of taking such a risk would be greater than $200 billion a year.

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[1] Sullivan, Andrew. "The Cannabis Closet", *The Daily Dish*, April 10, 2009

[2] New York Times, San Jose Mercury News

Appendix A: Price Data Sources

System to Retrieve Information on Drug Enforcement/ Illegal Drug Price and Purity Report 2007

Table 1: Quarterly Data by Quantity Level, 2007 Dollars

Year-Quarter	<10 g	10<g<100	>100g
1997-1	$5.65	$6.27	$2.67
1997-2	$6.02	$5.00	$3.07
1997-3	$11.21	$4.97	$2.84
1997-4	$20.77	$5.56	$2.97
1998-1	$9.15	$4.85	$3.06
1998-2	$6.37	$6.61	$2.23
1998-3	$5.34	$8.76	$2.43
1998-4	$5.99	$4.99	$3.76
1999-1	$7.63	$8.65	$2.46
1999-2	$6.94	$12.17	$2.56
1999-3	$6.74	$5.85	$2.58
1999-4	$7.73	$5.49	$2.79
2000-1	$7.69	$4.36	$2.27
2000-2	$8.05	$3.79	$2.33
2000-3	$9.58	$6.67	$2.04
2000-4	$6.53	$4.92	$2.66
2001-1	$8.31	$6.11	$2.26
2001-2	$17.73	$6.43	$2.61
2001-3	$7.29	$4.77	$3.19
2001-4	$9.00	$6.77	$3.05
2002-1	$10.13	$6.57	$3.42
2002-2	$10.48	$11.23	$2.42
2002-3	$9.70	$4.78	$3.13
2002-4	$15.26	$11.78	$3.10
2003-1	$12.36	$4.80	$2.40
2003-2	$11.88	$5.91	$2.33
2003-3	$10.21	$4.40	$2.59
2003-4	$12.14	$8.47	$2.39
2004-1	$10.87	$5.68	$2.85
2004-2	$10.45	$5.92	$2.35
2004-3	$9.31	$5.95	$1.83
2004-4	$11.76	$8.77	$2.19
2005-1	$10.29	$5.21	$3.42

2005-2	$10.15	$15.51	$2.65
2005-3	$9.57	$10.73	$2.65
2005-4	$13.54	$13.55	$2.47
2006-1	$10.42	$7.82	$2.09
2006-2	$10.01	$6.37	$2.42
2006-3	$9.27	$13.69	$2.13
2006-4	$14.69	$8.74	$2.10
2007-1	$18.01	$4.43	$2.75
2007-2	$14.47	$8.36	$1.69
2007-3	$10.48	$7.38	$1.75
2007-4	$13.54	$6.07	$2.76

Table 2: Annual Average by Quantity Level, 2007 Dollars

Year	**<10 g**	**10<g<100**	**>100g**
1997	$10.91	$5.45	$2.89
1998	$6.71	$6.30	$2.87
1999	$7.26	$8.04	$2.60
2000	$7.96	$4.94	$2.33
2001	$10.58	$6.02	$2.78
2002	$11.39	$8.59	$3.02
2003	$11.65	$5.90	$2.43
2004	$10.60	$6.58	$2.31
2005	$10.89	$11.25	$2.80
2006	$11.10	$9.16	$2.19
2007	$14.13	$6.56	$2.24
Average	$10.29	$7.16	$2.58

Derived Price Indices from National Survey on Drug Use and Health data/Gettman (2006)

Table 3: Gettman/NSDUH Retail Price Index, Dollars of Given Year

Year	$/g	$/oz	$/lb
2001	$5.91	$168	$2,680
2002	$5.47	$155	$2,483
2003	$5.83	$165	$2,644
2004	$6.79	$192	$3,078
2005	$6.14	$174	$2,783

Table 4: Gettman/NSDUH Producer Price Index, Dollars of Given Year, Dollars per Pound

Year	Retail	Wholesale	Distributor	Farm	Index
2001	$2,680	$2,238	$1,809	$1,340	$1,575
2002	$2,483	$2,073	$1,676	$1,241	$1,459
2003	$2,644	$2,208	$1,785	$1,322	$1,554
2004	$3,078	$2,570	$2,078	$1,539	$1,808
2005	$2,783	$2,324	$1,878	$1,391	$1,635

Table 5: Gettman/NSDUH Producer Price Index, 2007 Dollars, Dollars per Gram

	Retail	Wholesale	Distributor	Farm	Index
2001	$7.03	$5.87	$4.74	$3.51	$4.13
2002	$6.36	$5.31	$4.29	$3.18	$3.74
2003	$6.64	$5.55	$4.48	$3.32	$3.90
2004	$7.49	$6.25	$5.05	$3.74	$4.40
2005	$6.55	$5.47	$4.42	$3.27	$3.85
Average	$6.81	$5.69	$4.60	$3.41	$4.00

High Times Source Data, By Month, Dollars per Ounce by Quality, Dollars of Given Year

High Times Trans-High Market Quotations (THMQ) Price Indices, September 2004 – January 2009 Source Websites.

SEPTEMBER 2004
http://hightimes.com/thmq/admin/4065, accessed 3/10/09

OCTOBER 2004
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NOVEMBER 2004
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DECEMBER 2004
http://hightimes.com/thmq/admin/4072, accessed 3/10/09

JANUARY 2004
http://hightimes.com/thmq/admin/4048, accessed 3/10/09

FEBRUARY 2005
http://hightimes.com/thmq/admin/4051, accessed 3/10/09

MARCH 2005
http://hightimes.com/thmq/admin/4054, accessed 3/10/09

APRIL 2005
http://hightimes.com/thmq/admin/4056, accessed 3/10/09

MAY 2005
http://hightimes.com/thmq/admin/4059, accessed 3/10/09

JUNE 2005
http://hightimes.com/thmq/admin/4061, accessed 3/10/09

AUGUST 2005
http://hightimes.com/thmq/admin/4063, accessed 3/10/09

SEPTEMBER 2005
http://hightimes.com/thmq/admin/4066, accessed 3/10/09

OCTOBER 2005
http://hightimes.com/thmq/admin/4068, accessed 3/10/09

NOVEMBER 2005
http://hightimes.com/thmq/admin/4071, accessed 3/10/09

DECEMBER 2005
http://hightimes.com/thmq/admin/4073, accessed 3/10/09

JANUARY 2006
http://hightimes.com/thmq/admin/4049, accessed 3/10/09

FEBRUARY 2006
http://hightimes.com/thmq/admin/4052, accessed 3/10/09

MARCH 2006
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APRIL 2006
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JANUARY 2007
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http://hightimes.com/thmq/admin/4053, accessed 3/10/09

AUGUST 2007
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MAY 2008
http://hightimes.com/lounge/admin/4264, accessed 3/10/09

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AUGUST 2008
http://hightimes.com/lounge/ht_admin/4439, accessed 3/10/09

SEPTEMBER 2008
http://hightimes.com/lounge/ht_admin/4571, accessed 3/10/09

OCTOBER 2008
http://hightimes.com/lounge/ht_admin/4690, accessed 3/10/09

NOVEMBER 2008
http://hightimes.com/lounge/ht_admin/4777, accessed 3/10/09

DECEMBER 2008
http://hightimes.com/lounge/ht_admin/4875, accessed 3/10/09

JANUARY 2009
http://hightimes.com/lounge/ht_admin/4945, accessed 3/10/09

Table 6: High Times THMQ Price Indices, September 2004 – January 2009

Year	"Current Index"	"Kind"	"Mids"	"Schwag"
August 2004	$327	$482	$301	$122
September 2004	$307	$446	$283	$99
October 2004	$316	$447	$288	$110
November 2004	$324	$461	$305	$118
December 2004	$324	$500	$315	$92
January 2005	$320	$421	$312	$111
February 2005	$320	$421	$312	$111
March 2005	$352	$582	$302	$117
April 2005	$312	$409	$263	$101
May 2005	$329	$440	$258	$86
June 2005	$320	$445	$258	$74
July 2005	$328	$424	$303	$60
August 2005	$370	$446	$255	$84
September 2005	$332	$469	$273	$87
October 2005	$342	$424	$270	$91
November 2005	$342	$424	$270	$91
December 2005	$352	$460	$279	$97
January 2006	$335	$438	$266	$75
February 2006	$347	$461	$258	$86
March 2006	$336	$431	$266	$89
April 2006	$342	$434	$266	$93
May 2006	$344	$425	$266	$94
June 2006	$380	$448	$276	$99
September 2006	$380	$448	$276	$94
October 2006	$360	$434	$278	$99
December 2006	$348	$436	$258	$93
January 2007	$335	$438	$259	$75
February 2007	$349	$419	$279	$92
July 2007	$389	$451	$279	$83
August 2007	$388	$437	$283	$103
April 2008	$346	$459	$276	$88
May 2008	$371	$451	$275	$83

June 2008	$376	$438	$256	$64
July 2008	$359	$418	$279	$100
August 2008	$393	$467	$256	$94
September 2008	$389	$458	$293	$98
October 2008	$361	$468	$297	$93
November 2008	$344	$427	$279	$100
December 2008	$358	$465	$262	$88
January 2009	$394	$452	$263	$93

Table 7: High Times THMQ Price Indices, Annual Average by Quality, Price per Ounce, Dollars of Given Year

Year	"Non-adjusted"	"Kind"	"Mid"	"Schwag"
2004	$319.60	$467.20	$298.40	$108.20
2005	$334.90	$447.10	$279.60	$92.50
2006	$352.40	$439.40	$267.80	$91.30
2007	$365.30	$436.30	$275.00	$88.25
2008	$369.10	$450.30	$273.60	$90.10

Table 8: High Times THMQ Price Indices, Annual Average by Quality, Price per Gram, 2007 Dollars

Year	"Non-adjusted"	"Kind"	"Mid"	"Schwag"
2004	**$12.44**	**$18.18**	**$11.61**	**$4.21**
2005	**$12.60**	**$16.83**	**$10.52**	**$3.48**
2006	**$12.94**	**$16.13**	**$9.83**	**$3.35**
2007	**$12.89**	**$15.39**	**$9.70**	**$3.11**
2008	**$12.89**	**$15.73**	**$9.56**	**$3.15**
Average	**$12.75**	**$16.45**	**$10.25**	**$3.46**

Appendix B: Quantity Data from Leading Source Nations

Table 1: Mexican Quantity Data,
INCSR Reports 2002-2009 and NDTA, 2006-2009

Year	Hectares Eradicated	Net Cannabis Production (Metric Tons, MT)	Marijuana Seized (MT)	Net Hectares Cultivated
1997		8600		4800
1998		8300		4600
1999		6700		3700
2000		7000		3900
2001	28699	7400		4100
2002	30775	7900	1633	4400
2003	36585	13500	2248	7500
2004	30851	10440	2208	5800
2005	30842	10100	1786	5600
2006	30162	15500	1902	
2007	22348		2194	
2008	15756	15800	1650	

Table 2: Colombian Quantity Data, INCSR 2007

Year	Seizures, MT
1997	136
1998	69
1999	65
2000	46
2001	36.6
2002	76.9
2003	126.1
2004	
2005	139.9
2006	105.7
2007	
2008	

Table 3: Canadian Seizure and Eradication Data,
NDTA reports 2005, 2006, 2008

Year	Seized at US Border, KG (2008 report)	Seized at US Border, KG (2006 report)	Plants Eradicated (2005 report)	Seized Domestically (2005 report)
2001	3549	3601		
2003	7851	8370		
2004	10288	11183	1400026	47442
2005	4147	9236		
2006	9458		2055715	56226
2007	4170		1749057	13154

Table 4: Jamaican Seizures and Eradication, INCSR Reports 2002, 2007, 2008

Year	KG Seized (2007, 2008 reports)	Seizures, MT, 2002 report	Hectares Eradicated, 2002 Report
1997		24	743
1998		35	705
1999		56	894
2000		55	517
2001		68	332
2002		26	80
2003	36603.6	36.6	444.639
2004	20952.14	20.9	411.64
2005	19777.31	17.6	422.96
2006	59770.69		524

Appendix C: Additional Tables

Table 1: Final Range of Estimates, Unit Taxes, 2007 Quantity

Unit Tax	Estimate of Q2	Implied Ad-Valorem (%)	Expected Tax Revenue	100% Compliance
Best-guess Range: P_0 = \$11.12, P_1 = \$3.05, Q_0 = 70,535,634,986 grams, ε_D = -0.857				
\$2.00	103,551,008,751	66%	\$186,391,815,751	\$207,102,017,501
\$3.00	98,115,315,032	98%	\$264,911,350,587	\$294,345,945,097
\$4.00	92,679,621,314	131%	\$333,646,636,730	\$370,718,485,256
\$5.00	87,243,927,596	164%	\$392,597,674,181	\$436,219,637,979
\$6.00	81,808,233,877	197%	\$441,764,462,938	\$490,849,403,265
\$7.00	76,372,540,159	230%	\$481,147,003,003	\$534,607,781,114
\$8.07	70,535,634,986	265%	\$512,542,217,484	\$569,491,352,760
Minimum Range: P_0 = \$11.12, P_1 = \$1.52, Q_0 = 21,502,802,651 grams, ε_D = -0.720				
\$2.00	32,079,175,472	131%	\$57,742,515,850	\$64,158,350,945
\$3.00	30,687,234,712	197%	\$82,855,533,722	\$92,061,704,135
\$4.00	29,295,293,951	262%	\$105,463,058,225	\$117,181,175,805
\$5.00	27,903,353,191	328%	\$125,565,089,358	\$139,516,765,954
\$6.00	26,511,412,430	394%	\$143,161,627,123	\$159,068,474,581
\$7.00	25,119,471,670	459%	\$158,252,671,519	\$175,836,301,687
\$9.60	21,502,802,651	630%	\$185,751,167,417	\$206,390,186,019
Maximum Range: P_0 = \$11.12, P_1 = \$7.23, Q_0 = 175,146,010,120 grams, ε_D = -0.994				
\$2.00	204,783,989,049	28%	\$368,611,180,289	\$409,567,978,098
\$3.00	189,127,130,244	41%	\$510,643,251,659	\$567,381,390,732
\$4.00	173,470,271,439	55%	\$346,940,542,877	\$693,881,085,754
\$5.00	157,813,412,633	69%	\$394,533,531,583	\$789,067,063,167
\$6.00	142,156,553,828	83%	\$426,469,661,484	\$852,939,322,968
\$7.00	126,499,695,023	97%	\$442,748,932,579	\$885,497,865,159
\$3.89	175,146,010,120	54%	\$613,654,496,893	\$681,838,329,881
Mid-point Range 1: P_0 = \$11.12, P_1 = \$2.29, Q_0 = 46,019,218,818 grams, ε_D = -0.789				
\$2.00	68,323,015,061	87%	\$122,981,427,110	\$136,646,030,122
\$3.00	65,060,342,677	131%	\$175,662,925,228	\$195,181,028,031
\$4.00	61,797,670,293	175%	\$222,471,613,054	\$247,190,681,171
\$5.00	58,534,997,909	219%	\$263,407,490,590	\$292,674,989,544
\$6.00	55,272,325,525	262%	\$298,470,557,834	\$331,633,953,149
\$7.00	52,009,653,141	306%	\$327,660,814,787	\$364,067,571,985
\$8.84	46,019,218,818	386%	\$365,965,366,155	\$406,628,184,616
Mid-point Range 2: P_0 = \$11.12, P_1 = \$5.14, Q_0 = 122,840,822,553 grams, ε_D = -0.926				

$2.00	163,566,261,940	39%	$294,419,271,491	$327,132,523,879
$3.00	153,342,449,612	58%	$414,024,613,953	$460,027,348,836
$4.00	143,118,637,285	78%	$515,227,094,224	$572,474,549,138
$5.00	132,894,824,957	97%	$598,026,712,306	$664,474,124,785
$6.00	122,671,012,629	117%	$368,013,037,888	$736,026,075,776
$7.00	112,447,200,302	136%	$393,565,201,056	$787,130,402,112
$5.98	122,840,822,553	116%	$661,504,176,505	$735,004,640,561

Table 2: Final Range of Estimates, Ad-Valorem Taxes, 2007 Quantity

Unit Tax	Estimate of Q2	Implied Ad-Valorem (%)	Expected Tax Revenue	100% Compliance
Best-guess Range: P0 = $11.12, P1 = $3.05, Q0 = 70,535,634,986 grams, ε_D = -0.857				
30%	109,450,426,474	$0.91	$90,101,799,402	$100,113,110,446
40%	107,793,103,236	$1.22	$118,316,609,964	$131,462,899,960
50%	106,135,779,998	$1.52	$145,621,859,241	$161,802,065,824
60%	104,478,456,760	$1.83	$172,017,547,233	$191,130,608,036
70%	102,821,133,522	$2.13	$197,503,673,938	$219,448,526,598
80%	101,163,810,284	$2.44	$222,080,239,359	$246,755,821,509
90%	99,506,487,046	$2.74	$245,747,243,493	$273,052,492,770
265%	70,535,634,986	$8.07	$512,542,217,484	$569,491,352,760
Minimum Range: P_0 = $11.12, P_1 = $1.52, Q_0 = 21,502,802,651 grams, ε_D = -0.720				
30%	34,226,460,483	$0.46	$14,087,956,420	$15,653,284,911
40%	34,014,261,646	$0.61	$18,667,484,318	$20,741,649,242
50%	33,802,062,810	$0.76	$23,188,783,427	$25,765,314,919
60%	33,589,863,973	$0.91	$27,651,853,749	$30,724,281,943
70%	33,377,665,136	$1.07	$32,056,695,283	$35,618,550,314
80%	33,165,466,299	$1.22	$36,403,308,028	$40,448,120,031
90%	32,953,267,462	$1.37	$40,691,691,986	$45,212,991,095
630%	21,502,802,651	$9.60	$185,751,167,417	$206,390,186,019
Maximum Range: P_0 = $11.12, P_1 = $7.23, Q_0 = 175,146,010,120 grams, ε_D = -0.994				
30%	202,138,904,302	$2.17	$394,584,614,121	$438,427,349,023
40%	190,819,303,516	$2.89	$496,650,963,881	$551,834,404,313
50%	179,499,702,730	$3.61	$583,986,386,169	$648,873,762,410
60%	168,180,101,944	$4.34	$364,772,711,658	$729,545,423,315
70%	156,860,501,158	$5.06	$396,924,693,514	$793,849,387,028
80%	145,540,900,372	$5.78	$420,892,826,774	$841,785,653,549
90%	134,221,299,586	$6.51	$436,677,111,438	$873,354,222,877
54%	175,146,010,120	$3.89	$613,654,496,893	$681,838,329,881
Mid-point Range 1: P_0 = $11.12, P_1 = $2.29, Q_0 = 46,019,218,818 grams, ε_D = -0.789				

30%	72,610,111,716	$0.69	$44,830,581,738	$49,811,757,486
40%	71,864,029,011	$0.91	$59,159,918,648	$65,733,242,942
50%	71,117,946,307	$1.14	$73,182,160,391	$81,313,511,545
60%	70,371,863,602	$1.37	$86,897,306,965	$96,552,563,295
70%	69,625,780,898	$1.60	$100,305,358,372	$111,450,398,191
80%	68,879,698,194	$1.83	$113,406,314,611	$126,007,016,235
90%	68,133,615,489	$2.06	$126,200,175,682	$140,222,417,425
386%	46,019,218,818	$8.84	$365,965,366,155	$406,628,184,616
Mid-point Range 2: P_0 = $11.12, P_1 = $5.14, Q_0 = 122,840,822,553 grams, ε_D = -0.926				
30%	168,250,659,164	$1.54	$233,470,254,414	$259,411,393,794
40%	162,996,250,020	$2.06	$301,572,080,212	$335,080,089,124
50%	157,741,840,877	$2.57	$364,813,109,839	$405,347,899,821
60%	152,487,431,733	$3.08	$423,193,343,296	$470,214,825,885
70%	147,233,022,590	$3.60	$476,712,780,583	$529,680,867,315
80%	141,978,613,446	$4.11	$525,371,421,700	$583,746,024,111
90%	136,724,204,303	$4.63	$569,169,266,647	$632,410,296,274
116%	122,840,822,553	$5.98	$661,504,176,505	$735,004,640,561

Table 3: Average THC Content in U.S., UNODC and NDTA Reports

Year	% THC
1997	5.01
1998	4.91
1999	4.59
2000	5.3
2001	6.1
2002	7.2
2003	7.14
2004	8.13
2005	8.02
2006	8.8

Table 4: Annual Consumer Price Index, Bureau of Labor Statistics

Year	Consumer Price Index
1997	0.017
1998	0.016
1999	0.027
2000	0.034
2001	0.016
2002	0.024
2003	0.019
2004	0.033
2005	0.034
2006	0.025
2007	0.041

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