European Monitoring Centre
for Drugs and Drug Addiction

TECHNICAL REPORT

Monitoring and evaluating changes in cannabis policies: insights from the Americas

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About this report

This report provides an overview of the changes in cannabis policies in the Americas and the evidence emerging from evaluations of their impact. Highlighting the challenges in monitoring and evaluating regulatory changes in the drugs field, it will be of particular interest to those involved in planning or evaluating any changes to cannabis regulation.

About the EMCDDA

The European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) is the central source and confirmed authority on drug-related issues in Europe. For over 20 years, it has been collecting, analysing and disseminating scientifically sound information on drugs and drug addiction and their consequences, providing its audiences with an evidence-based picture of the drug phenomenon at European level.

The EMCDDA's publications are a prime source of information for a wide range of audiences including: policymakers and their advisors; professionals and researchers working in the drugs field; and, more broadly, the media and general public. Based in Lisbon, the EMCDDA is one of the decentralised agencies of the European Union.

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Executive summary

Over the past 50 years, several jurisdictions in Europe, Australia and the Americas have reduced the penalties associated with using or possessing small amounts of cannabis. As of December 2019, Canada, Uruguay and 10 US states have gone further and passed laws that license the production and retail sale of cannabis, mostly by private companies, to adults for non-medical — sometimes referred to as recreational — purposes ([1]). With discussions about alternatives to cannabis prohibition becoming more common in some parts of the world, there is a growing interest in learning from the cannabis policy changes in the Americas.

To learn more about these new cannabis regimes and their consequences, the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) commissioned a review of the changes governing recreational cannabis policies in the Americas and an overview of preliminary evaluations. Findings from this research are intended to inform discussions about the development of a framework for monitoring and evaluating policy developments related to cannabis regulatory reform. Key insights include the following.

- In addition to the populations of Canada and Uruguay, more than 25 % of the US population lives in states that have passed laws to legalise and regulate cannabis production, sales and possession/use for recreational purposes. In the US, allowing licensed production and sales is often at the discretion of sub-state jurisdictions, which may impose further zoning restrictions on cannabis-related activities. This variation can complicate analyses that attempt to compare legalisation and non-legalisation states, especially when the outcome data are not representative at state level.

- The peer-reviewed literature on cannabis legalisation is nascent, and we observe conflicting results depending on which data and methods are used, as well as which implementation dates and policies are considered. It is important to remain sceptical of early studies, especially those that use a simple binary variable to classify legalisation and non-legalisation states. This scepticism should extend to the many studies that fail to account for the existence of robust commercial medical cannabis markets that predate non-medical recreational cannabis laws. Even if a consensus develops on certain outcomes, it does not mean that a relationship will hold over time. Changes in the norms about cannabis use and potentially other substances, the maturation of markets and the power of private businesses (if allowed) could lead to very different outcomes 15 or 25 years after recreational cannabis laws have passed. Evaluations of these changes must be considered an ongoing exercise, not something that should happen in the short term.

- One area in which there seems to be a consensus — so far — is with respect to cannabis-involved hospitalisations and emergency department (ED) visits in Colorado. While studies have observed increases in the number of adverse events after changes in medical or recreational supply, they tend to utilise a simple pre-post design without a control group. Thus, they do not produce causal estimates, and it is possible that some increases could be due to changes in reporting or measurement. For example, it is unclear if increases in the number of ED visits and hospitalisations are due to a greater willingness on the part of individuals to report the use of cannabis and/or if doctors are more aware of acute cannabis intoxication after the policy change and are now more likely to screen or confirm with urinalysis.

- One insight arising from the evaluations of the regulatory changes in the Americas to date is the importance of the amount and range of data collected before the change; simply

([1]) Two other US jurisdictions, the state of Vermont and the District of Columbia, also allow the cultivation and possession of cannabis for adults but do not permit its commercialization.

comparing past-month prevalence rates will not tell us much about the effect of the change on health. While US jurisdictions have been moving quickly to legalise the use of cannabis, the data infrastructure for evaluating these changes is limited. In contrast, Canada has made important efforts to field new surveys and create new data collection programmes in anticipation of legal changes. This highlights the importance of any jurisdictions that are considering changes to the regulatory framework for cannabis starting to think about improving data collection and analysis systems in advance.

- While there is much to learn from what is happening in the Americas, policy discussions should not be limited to approaches that have been implemented there. There are several regulatory tools (e.g. minimum pricing, potency-based taxes) that receive very little attention — if any — that could have important consequences for health, public safety and/or social equity. It needs to be recognised that all decisions of this nature involve trade-offs and acknowledging that individuals (and governments) have different values and preferences for risk when it comes to cannabis policy is important for productive debates on this controversial topic.

Foreword

The EMCDDA exists to facilitate an evidence-informed understanding of issues that are important for developing better drug-related policies and actions across Europe. In our series of reports, *Cannabis: controversies and challenges*, we focus attention on an illicit drug with a long history of use that has recently been an area of rapid policy development and intense European and wider international drug policy debate. In some countries, questions on what constitutes an appropriate policy response to cannabis have become both more topical and important. The aim of this set of publications is to explore, in an objective and neutral manner, some of the complex issues that exist in this fast-changing area.

The paper *Medical use of cannabis and cannabinoids: questions and answers for policymaking*, published in December 2018, provided an overview of developments in the way in which countries and jurisdictions are regulating the use of cannabis and cannabinoids for medical purposes. In this report, the latest in the series, the focus is shifted to recent changes to regulatory systems in the Americas that permit the consumption of cannabis by adults for non-medical, recreational purposes. In order to improve our understanding of these new cannabis regimes and their consequences, the EMCDDA commissioned RAND Europe and the RAND Drug Policy Research Center to undertake a review of the changes to recreational cannabis policies in the Americas and produce an overview of the evidence emerging from preliminary evaluations.

At this stage the evidence base is still insufficient to comment with any certainty on the impact of the changes that are occurring in the Americas. However, this is a rapidly developing area and this review provides a detailed summary of the current evidence base. The EMCDDA will continue to follow up on developments to help inform the European debate in this area.

Importantly, this review, in addition to providing EU audiences with a clearer picture of the developments occurring in the Americas, also highlights some of the challenges associated with monitoring and evaluating regulatory changes in the drugs field. We trust that this report will be of particular use to those involved in planning or evaluating any changes to cannabis regulation.

Alexis Goosdeel

Director, EMCDDA

1. Introduction

The cannabis policy landscape in the Americas is dramatically changing. Individual states in the US began liberalising their cannabis laws as far back as the 1970s, when several of them reduced or removed criminal penalties for possession of small amounts of cannabis. Starting in the 1990s, US states began to allow individuals to possess cannabis for qualified medical conditions. In contrast to subsequent European systems, medical cannabis in the US was primarily voter initiated and allowed people to grow and smoke non-standardised cannabis herb for a wide range of medical indications. These early medical cannabis reforms maintained state-level prohibition, except for a class of patients who obtained recommendations from authorised medical practitioners.

Distinct from, and in marked contrast to, these earlier medical cannabis reforms, voters in the US states of Colorado and Washington passed ballot initiatives in 2012 to repeal the prohibition on adult, non-medical cannabis and to license for-profit firms to produce and sell the drug to adults aged 21 years and over. Since the 2012 election, 10 more US jurisdictions have approved commercial models for non-medical cannabis, and in two others (Vermont and the District of Columbia — DC) non-commercial approaches have been adopted.

However, reforms to cannabis supply laws in the Americas are not limited to the US. In late 2013, Uruguay became the first country in the world to repeal prohibition on cannabis supply for non-medical markets; however, its approach is more restrictive than the regulated commercial regimes adopted in the US. Registered adults in that country could begin growing a small number of plants at home or join a social club in late 2014; by mid-2017, individuals could buy rationed amounts of cannabis, grown by state-authorised producers, in licensed pharmacies that chose to sell it. In June 2018, Canada became the second country to legalise cannabis production and supply for non-medical purposes; retail stores opened in some provinces, starting in October 2018. In addition, other countries in the Americas have passed laws to permit access to cannabis or cannabis-derived products for medical purposes.

Apart from the regulatory changes in the Americas, which are the focus of this report, changes are occurring globally. For example, the Dutch government is implementing its 2017 commitment to experiment with a closed supply chain to coffee shops, while Malta's government has taken steps to launch a national debate on whether or not there could be recreational cannabis use, and how this should be implemented. In 2018, the parties forming the government of Luxembourg reached an agreement that may allow for the future sale of cannabis to residents, while the highest courts in South Africa and Georgia have initiated reforms based on human rights that permit the consumption of cannabis in private settings, but not its sale. Other countries have not formally legalised cannabis but may have reduced the emphasis that they place on control or introduced some formal or informal tolerance for personal use of the drug.

The focus of this report is on changes that are relevant to recreational cannabis, sometimes referred to as adult or non-medical cannabis, with an emphasis on the implementation of commercial models in US states. The report does not separately evaluate medical cannabis reforms in the US or elsewhere. These are discussed only insofar as they help to explain the context in which subsequent recreational cannabis reforms took place. Cannabis and cannabinoids are made available for medical use in a wide variety of ways; hence the term 'medical cannabis' can be used to describe many different products and forms of supply. For reviews of the evidence on the various medical regimes, see Pacula and Smart (2017), the EMCDDA (2018) report *Medical use of cannabis and cannabinoids — questions and answers for policymaking* and the accompanying summary of reviews (Hall, 2018). Similarly, this report does not examine reforms aimed at reducing criminal penalties for possession or use but focuses on the broader set of policy changes aimed at regulating the recreational cannabis market.

To learn more about these new cannabis regimes and their consequences, the EMCDDA commissioned a review of changes governing recreational cannabis policies in the Americas and an overview of preliminary evaluations. Findings from this research are intended to facilitate a better understanding among the EU audience of developments occurring in the Americas and to inform discussions about the framework necessary for monitoring and evaluating policy developments related to cannabis policy changes that might increase the availability of this substance within Europe.

This report is structured as follows: following this introduction, Section 2 provides the background to and context of recent developments in cannabis policies in the Americas, with a particular focus on the more mature state commercial markets in the US; Section 3 offers a description and typology of different policy approaches with supporting case summaries; Section 4 presents an assessment of early evidence of the impact of policy changes in this area; and Section 5 provides guidance for European policymakers considering regulatory changes in the cannabis area on the establishment of a comprehensive, monitoring and evaluation framework. Appendix A highlights some of the ongoing and planned studies of legalisation implementation and its consequences in the Americas.

2. Background to cannabis policy developments in the Americas

Changes in cannabis policy that introduce greater tolerance can take various forms. Countries in Europe and elsewhere have reduced penalties for low-level offences, have removed criminal sanctions for possession or use or have introduced formal or informal procedures that reduce the likelihood of sanctions being applied for some forms of personal possession or use. However, up to now these policy changes have taken place within the overall context of maintaining the prohibition of cannabis supply and not establishing a regulated market for the drug for recreational users. This is an important distinction, because efforts to repeal prohibition and replace it with rules governing production, distribution and possession/use of cannabis are expected to have a greater impact on public health and safety than amending laws related to possession or use. However, many jurisdictions in the Americas have begun to repeal the prohibition of cannabis, allowing licensed businesses to produce and supply it for a narrow set of qualified medical patients (i.e. *medical cannabis*) or any adult over a minimum age (i.e. *recreational cannabis*). The main focus of this report is on recent efforts aimed at replacing cannabis prohibition with regulated regimes that permit recreational cannabis. However, some information relating to medical cannabis regimes is also provided, as they have been a very common step in the evolution of cannabis regulatory developments in the Americas (Kilmer and MacCoun, 2017) and are therefore relevant to understanding the context of subsequent reforms in relation to recreational cannabis use.

The move towards changing cannabis laws to allow medical access is driven by multiple factors. Three common arguments are (1) the desire to improve the lives of patients who could immediately benefit from these products, particularly when they are produced in a manner that can ensure consistency and quality; (2) the desire to learn more about the medical benefits and risks of these products; and (3) the desire to take action to soften prohibition and improve civil liberties. Another driver of change that is becoming increasingly important in some jurisdictions is the desire to generate legal economic activity and tax revenues from cannabis businesses (Subritzky et al., 2016; Hall and Kozlowski, 2018).

It is also important to consider these medical laws when thinking about the move towards legalising recreational cannabis. As Table 2.1 makes clear, only a small minority of countries that allow medical cannabis have made the move towards permitting adults to access cannabis for recreational purposes. In contrast, Uruguay did not start developing a medical programme until after legislation for recreational cannabis was passed. This legislation was pushed by the government largely to reduce drug-related crime and violence associated with the cannabis trade (Aguiar and Musto, 2015). Despite its initial unpopularity with the citizens of Uruguay (Garat, 2015), it was signed into law in December 2013.

TABLE 2.1
Changes to cannabis supply laws in the Americas

Country	Implemented nationally	Year passed	Comments
		Medical	
United States	No	1996 onwards*	In total, 33 states and DC have passed laws to allow cannabis flowers and other products to be produced and distributed for qualifying conditions. Thirteen other states allow physicians to recommend or individuals to obtain CBD oils, but do not necessarily permit their production. This all remains illegal under federal law.
Canada	Yes	2001	Currently, all medical cannabis is supposed to be produced by federally licensed private companies and delivered by post. Efforts are being made to eliminate the illegal dispensaries that still operate in some jurisdictions. Registered patients may also cultivate a limited amount at home for their own personal needs.
Uruguay	Yes	2013	Production is licensed by state, and extracts are available in pharmacies for those with a physician's prescription. Currently products containing CBD and a low THC concentration are available for a set of conditions.
Chile	Yes	2015	There is limited access to cannabis-derived products approved by health authorities, which currently include only imported high-CBD/low-THC oils available in pharmacies. There is an ongoing pilot project with one domestic cultivator.
Jamaica	Yes	2015	Licences have been granted since 2017. As at mid-2018, there are a handful of cultivators and processors as well as two medical dispensaries. Regulations allow small- and large-scale production of medical cannabis for residents as well as tourist and export markets.
Colombia	Yes	2015	The decree signed in December 2015 permits medical cannabis under the national drug law. The decree was superseded by law. The Ministry of Health has licensed cultivators, although it is unclear how much cannabis production will be permitted. The law and accompanying regulations focus on export markets.
Brazil	Yes	2016	The health agency resolution allows the importation of cannabis oils for epilepsy and multiple sclerosis.
Argentina	Yes	2017	A law and a ministerial decree have directed the Ministry of Health to draft regulatory guidelines to allow the state to produce and patients to inscribe into a programme to obtain or import cannabis oils and other derivatives for treatment of qualifying conditions.
Mexico	Yes	2017	A legislative act and regulatory decree were passed in 2017 to permit the importation of medicinal products to treat qualifying conditions. Regulations have not yet been finalised.
Peru	Yes	2017	A law was passed to guide the Ministry of Health with regard to drafting appropriate regulations to allow doctors to prescribe and patients to obtain cannabis and cannabis derivatives.
		Recreational**	
United States	No	2012*	Ten states have passed laws to allow for-profit companies to produce and sell cannabis (Alaska, California, Colorado, Illinois, Massachusetts, Maine, Michigan, Nevada, Oregon and Washington) to anyone aged 21 years and over; DC and Vermont allow only home production and sharing of cannabis. Production and possession remain illegal under federal law.
Uruguay	Yes	2013	Residents aged 18 years and over must register with the government to either grow cannabis at home, join a collective or purchase cannabis from pharmacies. Home growing of cannabis and social clubs started operating in the latter half of 2014. State-licensed companies produce retail products sold in pharmacies. Sales began in mid-2017. The government determines the price and potency of cannabis sold in pharmacies. Pharmacy sales have slowly been introduced, partly because of issues pertaining to the access of financial institutions with branch offices in the US.
Canada	Yes	2018	In mid-2018, the Canadian parliament passed the Cannabis Act to permit adults to cultivate, process and use cannabis for recreational purposes. The law came into effect in October 2018. Under the law, the provinces are given regulatory power with regard to distribution, but federal law provides general rules on production, promotion, packaging and licensing.

* Federal law still prohibits cannabis. The date reflects the date when the first state passed a law.
** In October 2018, the Mexican Supreme Court ruled that prohibiting cannabis for personal use is unconstitutional; however, this does not technically legalise use and supply. The legislature is working to amend the law, to codify the ruling. For more information, see Lopez (2018).
THC, tetrahydrocannabinol — the principal intoxicative agent in cannabis; CBD, cannabidiol — a cannabinoid that has the potential to reduce certain maladies and attenuate some of the effects of THC.

Most of the changes have been limited to supplying cannabis for medicinal purposes, and there is an important variation in what these legal frameworks allow. These regulatory systems and the products that are available to patients differ from traditional medicinal formulations that contain synthetic cannabinoids (e.g. dronabinol or nabilone) or plant-derived preparations approved by the government (e.g. Sativex or Epidiolex). Some jurisdictions make it easy for patients to access a myriad of cannabis preparations, including raw or herbal products that can be smoked or vaporised (e.g. many US states, Canada), as well as various cannabis-derived preparations, such as vaporisable concentrates, tinctures, edibles and topicals. More restrictive markets only allow cannabis extracts with high levels of cannabidiol (CBD) and a trace or modest amounts of tetrahydrocannabinol (THC) (e.g. about a dozen US states, Chile, Brazil, Mexico) or limit the types or forms of cannabis available to patients (e.g. prohibiting smoking of herbal or raw cannabis).

However, in US states, recreational legalisation has followed the provision of medical cannabis, and multiple hypotheses have been offered about how the latter may have smoothed the transition to the former. Kilmer and MacCoun (2017) offer five potential explanations for the transition:

(a) it demonstrated the efficacy of using voter initiatives to change cannabis supply laws;

(b) it enabled the psychological changes needed to destabilise the 'war on drugs' policy stasis;

(c) it generated an evidence base that could be used to downplay concerns about non-medical legalisation;

(d) it created a visible and active cannabis industry;

(e) it revealed that the federal government would allow state and local jurisdictions to generate tax revenue from cannabis.

Of course, some of these reasons are specific to the US (e.g. state ballot initiatives and federalism). With respect to the visibility of the cannabis industry, Kilmer and MacCoun (2017) note the following:

> *The proliferation of medical dispensaries in the 2000s introduced the public to the idea of stand-alone stores selling [cannabis] products (and not just to those residing in states that allow medicinal [cannabis], as dispensaries are regularly featured in media stories across the country). Subsequent advertisements in alternative weekly newspapers and occasionally on billboards also exposed voters to this new quasi-legal industry.*
>
> *Of course, not everyone is thrilled with the establishment of medical dispensaries and the related advertising, and there is tremendous variation in what states allow and how they are regulated (Pacula et al. 2015). Further, even in states that allow dispensaries, some local jurisdictions have decided to prohibit them. But for those who see these dispensaries on a regular basis, they not only have a sense of what legalisation may look like but also may be desensitised to the idea of retail [cannabis]. In fact, some may conclude that allowing any adult to enter those stores instead of only those who have recommendations — which in some states are very easy to obtain (e.g., High Times 2016) — may not be a big change.*
>
> *Medical [cannabis] laws also created an industry looking to expand its market beyond medical patients. Indeed, it is hard to imagine that some of those developing, e.g., brands, new methods of ingestion, and improved production methods did not have their sights on a larger market. Although those in the advocacy community criticised the industry for not donating more to the campaigns (e.g., see quotes from Ethan Nadelmann in Freedlander 2016), some with a financial interest did make contributions.*

In Canada, a series of provincial and Supreme Court cases during the early 2000s gradually legalised the medical use of cannabis. The initial medical system developed at the national level slowly unfolded. In 2001, Canada enacted enabling legislation via the Controlled Drug and Substances Act to pass the Marihuana Medical Access Regulations (MMAR). This new set of regulations permitted

individuals with qualifying illnesses (which were listed by the regulation) to obtain medical cannabis. The initial programme was overly restrictive, so that many patients wishing to take cannabis for their condition had to source it from the illicit market (Fischer et al., 2015). Individuals were allowed to obtain cannabis by three different means: (1) by applying to access Health Canada's supply of dried cannabis via the postal system; (2) by applying for a personal-use production licence (i.e. to grow cannabis at home); or (3) by designating someone to cultivate on their behalf with a 'designated-person production licence'. This last provision was criticised for permitting unregulated and outright illicit sales (Fischer et al., 2015).

In response to concerns from law enforcement and other policymakers that the system governed by the MMAR was open to abuse, and after extensive consultations, the Harper government introduced the Marihuana for Medical Purposes Regulations (MMPR) in 2013 to further restrict and regulate the market by eliminating home-growing of cannabis and limiting designee production. Under the MMPR, only licensed producers could cultivate medical cannabis. Justin Trudeau became prime minister in 2015 and prioritised cannabis policy reform, including the legalisation of recreational cannabis. In 2016, the MMPR was struck down on constitutional grounds and was later superseded by the Access to Cannabis for Medical Purposes Regulations (ACMPR), which built on the existing framework for licensed commercial producers established under prior regulations while permitting patients to register to cultivate a small amount for personal medical use. Existing producers licensed under the ACMPR would later be deemed as such under the Cannabis Act.

While bricks and mortar medical dispensaries ([2]) were technically illegal under Canadian law, some jurisdictions allowed them to operate; other jurisdictions, such as Vancouver, eventually established some licensing and regulatory frameworks to control the growing retail industry (Johnson, 2015). As in multiple US states, this probably introduced some Canadians to the idea of stand-alone stores selling cannabis products as well as advertising such products. Many Canadian medical cannabis producers anticipated supplying the much larger recreational market. As cannabis is federally legal in Canada, some of these Canadian firms are listed on major US stock exchanges, in contrast to firms from the US, and some investors believe that they are 'poised to surge' (Chang, 2018). Yet projections of earnings and market valuation have been revised downwards, as sales have not met analyst expectations (Subramaniam, 2019).

Another important difference between Canada and most of the US states that have legalised recreational cannabis is the amount of public discussion and deliberation that took place before the policy change ([3]). After Prime Minister Trudeau announced his party's intentions to legalise cannabis, the Liberal government convened a task force that would spend nearly a year collecting information about regulating cannabis from several sources, ranging from international experts to domestic cannabis users. The task force's resulting report was released in December 2016. The report and subsequent recommendations helped shape the legislation introduced in April 2017. Soon after, there were several hearings in parliament about the bill. In the Senate's Standing Committee on Social Affairs, Science and Technology alone, there were 18 hearings. After more than 1 year of deliberation, the final bill received Royal Assent in June 2018, and legal sales began on 17 October 2018.

([2]) Shops with a physical location, as opposed to online or virtual businesses.

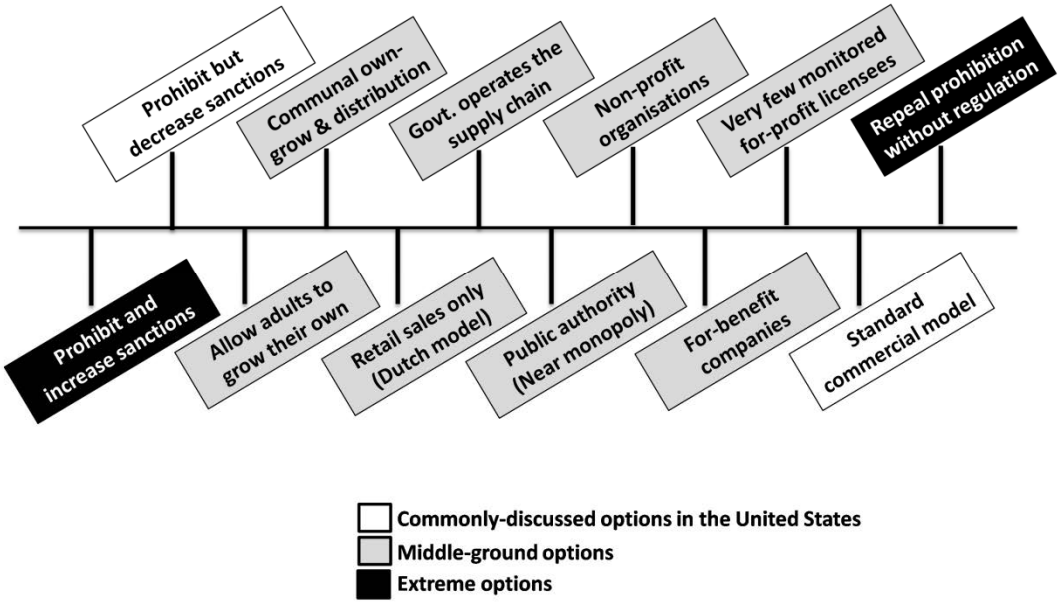
([3]) The most obvious exception is Vermont. Since 2014, the state legislature has seriously deliberated various legalisation proposals, from commercial models to the grow-at-home model, the latter being implemented in 2018. Other state authorities have commissioned expert reports assessing the impacts of legalisation (e.g. California) (Caulkins et al., 2015; Newsom et al., 2015).

3. A description and typology of different policy approaches

Jurisdictions considering alternatives to prohibition on cannabis supply are faced with a wide range of options from which to choose. Figure 3.1 presents some alternatives to the status quo prohibition of cannabis supply, including eight 'middle-ground' options between traditional prohibition and the standard for-profit commercial model, which is being adopted in an increasing number of US states. However, as will be made clear in this section, the for-profit option is not the only option that is pursued in the US, and both Uruguay and Canada have created regulatory regimes intended to limit the power of businesses.

It is also the case that these options are not mutually exclusive. Jurisdictions can allow both home production and commercial sales, a scenario that has occurred in most places that have legalised cannabis. Furthermore, the choices need not be the same at the various levels of cannabis markets (Wilkins, 2016). For example, it is possible to allow commercial businesses to produce cannabis but require that its distribution occurs via state-run retail stores, as is the case with alcohol in some jurisdictions, or via postal delivery, as is done in some parts of Canada.

FIGURE 3.1
Some alternatives to status quo cannabis supply prohibition



Source: Caulkins et al., 2015

3.1 US approaches

More than 25 % of the US population lives in 10 states where voters have passed laws permitting the commercialisation of cannabis production and distribution. Table 3.1 reports dates of passage for both medical and recreational legalisation as well as when retail dispensaries began selling recreational cannabis to adults.

While the commercial models in Colorado, Washington and California receive a great deal of attention, not all US states that have legalised cannabis have allowed commercial sales. Both DC and Vermont have opted for non-commercial access, allowing adults to privately grow and give away up to an ounce (28 g) of cannabis. In 2014, DC voters approved Initiative 71, which permits adults to grow up to six plants and to give away cannabis without remuneration ([4]). The law maintains a prohibition on selling cannabis and made public consumption a minor offence. The initiative has not been formally evaluated, but early media reports suggest that the new law has spurred unregulated transactions under the guise of giving cannabis to someone as a gift (Garcia, 2017).

In addition to DC, the state of Vermont legalised recreational cannabis in January 2018, which came into effect on 1 July of the same year. After more than two years of legislative deliberation and a government-sponsored report on the options and issues regarding legalisation, Vermont became the first state to repeal cannabis prohibition through legislation, rather than an initiative approved by voters. Similar to DC, Vermont's law permits adults aged over 21 years to grow six plants (up to two in flower) and to possess or give away up to an ounce of herbal cannabis. It does not permit sales. As in the case of DC, 'grey market' sales of cannabis, though technically illegal, may be occurring in Vermont's unregulated non-commercial system (Goldstein, 2018).

TABLE 3.1
Passage of recreational and medical cannabis laws in US states that permit these

State	Medical cannabis law passed*	Recreational cannabis law passed	Start of recreational sales
Alaska	1999	4 November 2014	29 October 2016
California	1996	8 November 2016	1 January 2018
Colorado	2000	6 November 2012	1 January 2014
DC	2010	4 November 2014	Not applicable
Illinois	2013	25 June 25 2019	Not yet open
Maine	2002	8 November 2016	Not yet open
Massachusetts	2013	8 November 2016	20 November 2018
Michigan	2008	6 November 2018	2 December, 2019
Nevada	2000	8 November, 2016	1 July 2017
Oregon	1998	4 November 2014	1 October 2015
Vermont	2004	22 January 2018	Not applicable
Washington	1998	6 November 2012	8 July 2014

*Medical cannabis laws have varied over the years. Here, we report the first year in which the state adopted a medical cannabis law, not necessarily when voters approved the initiative. Initially, these laws permitted qualifying individuals to possess cannabis. Over time, dispensaries and collective cultivation sites sprung up to supply growing patient demand. Since their inception, states have adopted various regulatory approaches, formalising commercial medical markets.

Source: National Conference of State Legislatures (2019)

([4]) Many but not all jurisdictions in the US allow citizens to propose initiatives for consideration by voters provided they obtain enough signatures.

3.2 Uruguay

In 2013, Uruguay became the first country in the modern era to legalise recreational cannabis use. Under the law, resident adults aged over 18 years can register with the state regulatory authority to access cannabis through one of three available supply channels. Registrants can switch from one supply channel to another, after changing their status with the regulatory authorities. Regardless of which supply stream users opt into, they are technically limited to 480 g per year. The three types of access are home cultivation, membership at a cannabis social club or retail sale via licensed pharmacies.

Individuals who decide to grow cannabis at home cannot cultivate more than six plants. As of May 2019, there were some 7 000 registered home growers. Clubs are limited to 45 members and can cultivate only up to 99 plants. Currently, there are 119 clubs in operation across the country, servicing about 3 600 members. Registered members are prohibited from obtaining more than their allowance of 480 g. Those opting to purchase at pharmacies must also register with authorities and are limited to purchasing no more than 10 g per week, with an annual cap of 480 g. There are just a few varieties of the plant on offer at pharmacies (i.e. regulators currently limit retail pharmacy sales to only a few strains), and authorities have aimed to keep potency below 10 % THC. According to regulators, there are currently 17 licensed pharmacies, mostly in the capital region, that sell cannabis to about 36 000 registered adults ([5]). There are no taxes on retail sales, but the government has set a price of UYU 40 (about EUR 1) per gram.

3.3 Canada

As a federal system, the new recreational cannabis law removes most prohibitions on cannabis from national drug control statutes (criminal prohibition on supply to or possession by minors or unregulated production remains). In most provinces, adults aged over 18 years can possess up to 30 g of herbal cannabis (or its equivalent in weight in other forms, such as concentrates ([6])). The law allows the cultivation, distribution and possession of cannabis by government-authorised entities. Federal law provides standards and a general framework for regulating cannabis, including requirements for an inventory tracking system, fees, quality and testing rules, restrictions on labelling and packaging, prohibitions on promotions aimed at enticing young people and bans on the types of products for sale. Federally licensed producers can be publicly traded, for-profit businesses, and there are no restrictions on alcohol and tobacco companies receiving a production licence.

Though the federal government has lifted prohibition, provinces have considerable power in designing rules governing distribution, taxation, and establishing age limits for purchase (some provinces opted to increase the minimum age to 19 years). Provinces are also tasked with enforcing their own regulations. Though federal law permits adults to cultivate up to four plants at home, some provinces have banned home cultivation. Provincial retail systems are still evolving, with some opting for public distribution channels similar to government-run alcohol stores.

What distinguishes Canada from the US states that have legalised cannabis is that the federal government led the effort to repeal prohibition, with the aim of reducing youth access, protecting public health and improving public safety by shrinking the illicit market. Unlike states in the US, Canadian provinces do not maintain their own competing criminal drug laws. Another important variation found in Canada's law is that it allows for mail order supply of cannabis, minimising the need for bricks and mortar stores. The federal government is also committed to public health and education campaigns aimed at reducing problematic use, including underage use.

([5]) See https://www.ircca.gub.uy/farmaciasadheridas/

([6]) Under Canadian law, 0.25 g of concentrates is equivalent to 1 g of dried herbal cannabis, and 15 g of solids containing cannabis is equivalent to 1 g of dried herbal cannabis.

4. An assessment of early evidence of the impact of policy changes in the United States

This section summarises the early evidence of the consequences of policy changes concerning recreational cannabis laws in the US. Here, we focus on the commercial cases that are specific to the US, given that these policy changes have unfolded over longer time periods, allowing for more evaluations of their impacts. They are also likely to have larger social impacts than non-commercial reforms such as home cultivation. Recreational cannabis laws are frequently referred to as 'recreational marijuana laws' and 'medical marijuana laws', as in US statutes and regulations cannabis is more commonly referred to as 'marijuana'. We refer to these as REC (recreational) or MED (medical) cannabis. Colorado and Washington were the first states in the US to pass REC laws, followed by Oregon and Alaska. Though other states, such as Maine and Illinois, have passed similar laws, they have yet to fully implement market regulations, or too little time has passed since they have been in place to allow the evaluation of the impacts. This analysis largely focuses on the pioneering states of Colorado and Washington, where more time has passed and more data have been collected.

Though REC laws have existed only in the last seven years, their adoption follows the passage of MED laws and, in some cases, robust commercial markets (see discussion in Section 2). The variation in MED laws and associated outcomes has been documented in scientific literature (Cerdá et al., 2012; Hasin et al., 2015; Pacula et al., 2015; Hall, 2018); as a result, we do not assess MED laws or their policy impacts here.

The consequences of the REC legal changes analysed here are likely to vary depending on the design and implementation of pre-existing medical cannabis laws and the size and scope of state commercial markets. For example, jurisdictions with commercial medical markets, lax restrictions on patient access and minimal regulatory burdens may not observe as many post-REC changes as states that restricted medical access to a narrow set of qualifying conditions or limited the number of dispensaries ([7]). In some cases, the adoption of REC laws is a marginal change (Colorado and California had large, loosely regulated medical markets for more than a decade before the adoption of REC laws, and the regulation of medical markets in Washington state did not occur until after the passage of REC laws); for other states, recreational laws are more novel (Massachusetts and Maine have had smaller or limited commercial medical markets for shorter time periods).

An assessment of the adoption of REC laws (and MED laws before them) must consider the underlying economic and social trends. Legalisation — but more importantly commercialisation — is likely to affect social norms by promoting use, normalising behaviours, increasing availability, introducing new products and lowering price (Caulkins et al., 2015; Hall and Lynskey, 2016; Subritzky et al., 2016; D'Amico et al., 2018). The extent to which any or all of these consequences resulted in a net benefit or net cost to society is unclear. Nevertheless, many consequences may depend on the timing of REC legalisation and its implementation and the shape in which both unfolded. Therefore, examining changes in commercial access (e.g. when stores opened) is perhaps a more accurate exposure variable than the date when a law was adopted. In addition to timing, an ideal measure for REC exposure should account for retail store density, something most of the literature has omitted in its analysis.

([7]) As the US federal government maintains the scheduling of cannabis as a Schedule I drug and because pharmacies require a federal licence to distribute controlled substances for medical purposes, medical cannabis products cannot be distributed through traditional pharmacies, even in states that permit cannabis for medicinal use. This is, in part, how and why the cannabis dispensary system started in the US.

4.1 Literature review selection criteria

We reiterate that the contemporary literature base on REC law impacts is thin, given that policies are still developing, markets are still maturing, and there are significant data gaps. Furthermore, states are adopting these legal changes against a backdrop of federal prohibition. Therefore, the full extent of these effects may change considerably in an environment in which the substance is legal at the national level (e.g. in Canada or Uruguay). Interstate trade and federal tax policy could have broad implications on the outcomes assessed here. Looking to the future, the immediate outcomes evaluated in this review may not reflect long-term outcomes, which may take decades or longer to develop. We therefore urge caution when interpreting the short-term measures and findings reported below.

That said, we assessed the emerging evidence on the outcomes of REC law changes. We excluded studies specific to MED, though the context of REC adoption and design is relative to a state's medical framework. These underlying legal and social factors related to MED may extend to differences in the outcomes reported post REC adoption. We also note that many studies specify various policy interventions, sometimes unclearly. Several peer-reviewed articles focus on REC enactment (after a law was passed to effect a change; in most cases, the prohibition on possession or home cultivation was lifted before implementation) or REC implementation (once the law is in effect and retail stores are open). Some ignore the distinction entirely, blending the two, rather than evaluating impacts in policy change after enactment or implementation.

We prioritise peer-reviewed articles over the grey literature or reports published by advocacy groups, but we have included a few well-designed working papers. In terms of the research design of articles, we highlight findings from quasi-experimental studies that include a control group or employ an interrupted time series method to assess policy impact ([8]). Studies that use state representative samples are prioritised over studies that have a non-representative or convenience sample. We also avoided including studies that evaluate measures at only one point in time or fail to include measures from pre- and post-implementation periods. Study design and methodology were an important component of this analysis. Our initial scan of the literature yielded many methodologically weaker studies that assessed outcomes of interest but were excluded for further review because they did not meet our methodological selection criteria. We have included all studies captured in our search in Appendix B, but we only assess outcomes of more rigorous studies in the body of this review.

Our search strategy focused on databases of peer-reviewed articles and working papers. We searched Google Scholar and PubMed for peer-reviewed articles in English and the National Bureau of Economic Research for working papers. We identified papers written and/or published up until July 2018, focusing on REC legalisation in the Americas; in addition six more recent peer-reviewed publications with credible control groups were added to the review during the publication process to ensure the findings were as up-to-date as possible (Kerr, D. et al., 2018; Anderson et al., 2019; Aydelotte et al., 2019; Cerdá et al., 2019; Everson et al., 2019; Lane and Hall, 2019) and insights from a new review (Smart and Pacula, 2019). Given that REC is a recent phenomenon, we concentrated our screening on articles published after 2012. The following search terms were used: *recreational; marijuana* or *cannabis*; and *legalisation*. We screened articles, focusing on evaluations relevant to REC and those that utilised methods that allowed for making inferences (e.g. pre-/post-analyses, interrupted time series, differences-in-differences).

4.2 Prevalence of use

Some analysts hypothesise that cannabis prevalence rates will change after recreational commercialisation (e.g. Caulkins et al., 2015; Hall and Lynskey, 2016). There are many reasons for

([8]) The one exception was a series of studies looking at adverse events pre/post REC legalisation in Colorado. We opted to include these studies, as they provide unique assessments of health outcomes relative to MED and REC legislation adoption in that state.

this, such as changing norms regarding cannabis use behaviours, product innovation, reductions in price and advertising (if allowed). There is greater concern regarding potential increases in youth prevalence, given the impacts of cannabis on the developing brain and the finding that early initiation is associated with poorer outcomes later in life (Fergusson and Boden, 2008). However, the consequences of REC legalisation will probably depend on how policy is implemented and the degree to which underlying attitudes and trends may be associated with recent changes in a state's medical cannabis policy. In turn, both medical and recreational policy changes may be a latent factor of underlying social attitudes regarding cannabis. Nevertheless, changes in supply, especially as it relates to *access* to cannabis through retail establishments and *price,* may have a greater impact on prevalence than a mere change in the law, which is why several have cautioned that the longer term effects of liberalisation policies may not be consistent with short-term effects (Caulkins et al., 2015; Cerdá et al., 2017).

Prevalence estimates are some of the most referenced statistics about the consequences of REC legalisation. The prevalence of cannabis consumption measures the proportion of a particular population that self-report using cannabis within a certain period, typically in the last month, in the last year or during their lifetime. The federal and state governments regularly estimate prevalence rates for different age cohorts using household or school surveys. The National Survey on Drug Use and Health (NSDUH) and the Monitoring the Future (MTF) surveys are two well-known, nationally representative surveys that regularly report cannabis prevalence, frequency of use and perception of risk estimates by age groups. The NSDUH also reports pooled 2-year, state-level prevalence estimates by age group. In addition to these surveys, Colorado and Washington ([9]) have conducted their own state-wide prevalence surveys of high school students (Healthy Kids Colorado Survey — HKCS; and Washington state's Healthy Youth Survey — HYS). Our scan of the literature also identified studies that evaluated changes in other repeated cross-sectional surveys, such as the National College Health Assessment survey or the National Alcohol Survey.

Figure 4.1 plots the past-month cannabis prevalence rates for the five states that passed REC laws before 2016 and for the entire country ([10]). Table 4.1 is included as a reference, indicating when MED/REC laws were adopted and when stores opened (except DC, which remained 'grow and give' only). Almost all states report increases in prevalence rates among the general population post REC legalisation, though prior trends suggest an increase in states' predated REC laws. Of course, simply examining trend data does not allow for strong causal inferences, and there is an emerging quasi-experimental literature attempting to control contextual factors and isolate these policy effects.

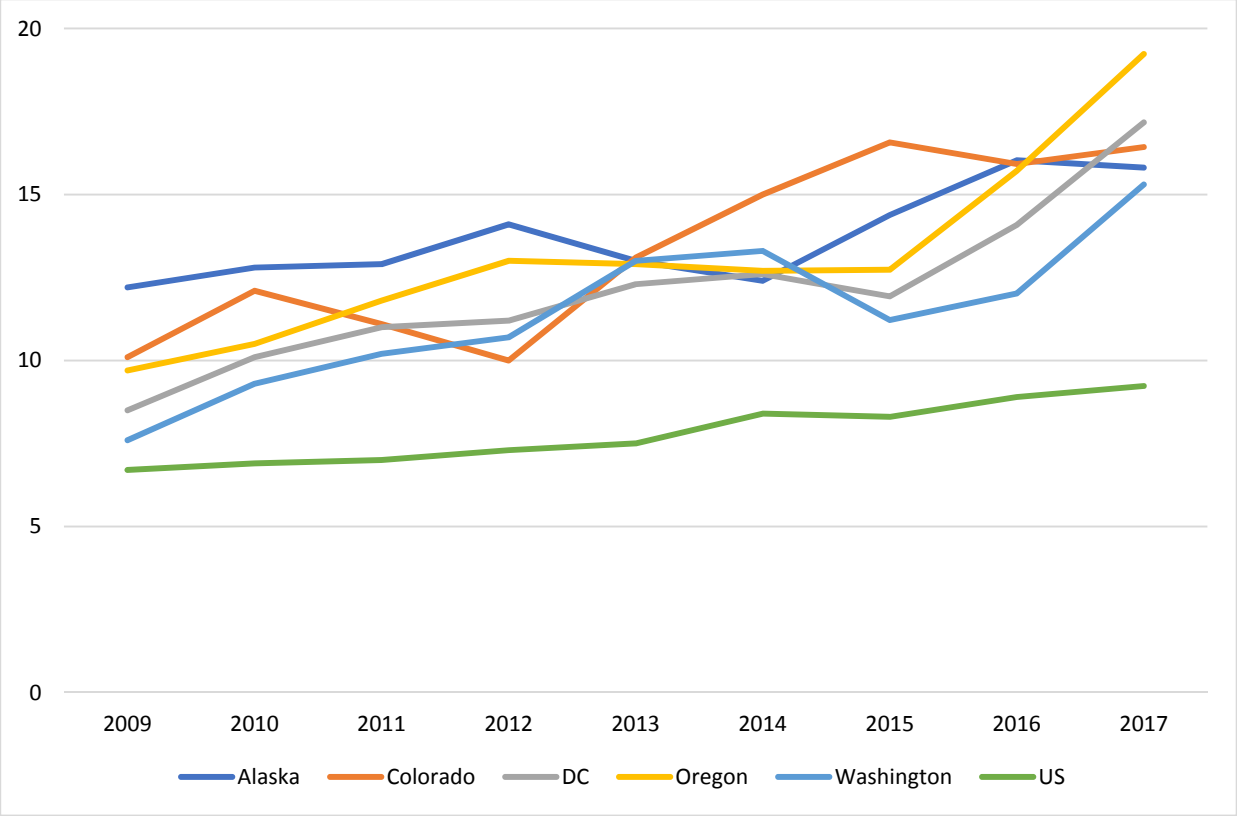
TABLE 4.1
Dates of MED/REC adoption and implementation for selected states

	Medical cannabis		Recreational cannabis	
State	Adoption	Year stores legally opened	Adoption	Implementation
Alaska	November 1998	Not applicable	November 2014	October 2016
Colorado	November 2000	2005	November 2012	January 2014
DC	November 1998	2010	November 2014	February 2015
Oregon	November 1998	2009	November 2014	October 2015
Washington	November 1998	Not applicable	November 2012	July 2014

([9]) We focus on these two states, given that there are more available post-treatment data, because recreational markets have been operating for over four years.

([10]) Additional trend data, including plots for individual states, are included in Appendix C.

FIGURE 4.1
Prevalence of cannabis use in the past month (%) among people aged 12 years and older



Source: NSDUH

So far, the peer-reviewed literature reports mixed findings regarding changes in self-reported prevalence after the adoption of REC laws. Studies in this nascent literature focused on adults are more likely to find an increase than those examining younger populations; indeed, there are some studies suggesting that youth prevalence may have declined. Table 4.2 compiles and summarises these findings described below.

Youth

In terms of changes among students, Cerdá et al. (2017) reported significant declines in the perception of harm and significant increases in past-month use of cannabis among 8th and 10th graders in Washington compared with states that did not adopt REC laws. The study employed a difference-in-difference approach to compare past-month prevalence rates between 2010-12 and 2013-15 in Colorado and Washington against rates in the rest of the US. The authors found that, in Washington, perception of harm reduced by 9 % for both grades ($p < 0.02$) and that past-month use increased by 5.0 ($p = 0.03$) and 3.2 ($p = 0.007$) percentage points for 8th and 10th graders, respectively (Cerdá et al., 2017). However, no significant difference in perception or use was reported for 12th graders in Washington or for any of the grades in Colorado.

The study treated REC enactment and implementation as one policy change. Though the law changed after voters approved the initiatives, stores were not authorised to sell cannabis products to customers until after the implementation. The different trends in prevalence may also be an artefact of the different nature of the medical cannabis policy environments in Washington and Colorado, the latter having a robust commercial market and allowing un-registered caregivers to cultivate a large number of plants for registered patients. This finding may also be an artefact of the data used. Using survey data from a much larger sample of students in Washington (Washington's Healthy Youth

Survey; HYS), Dilley et al. (2019) found that, if anything, there was a decrease in the past-month prevalence among 10th-grade students in Washington after REC enactment, according to state-wide surveys. Whether these results hold up when specific subgroups of students are examined remains to be seen.

Using the individual-level NSDUH data with state identifiers from 2008-2016, Cerdá et al. (2019) found no evidence that REC enactment influenced the past-month cannabis prevalence for those aged 12-17. Although it should be noted that only three states (Colorado, Washington and Oregon) had implemented REC markets with open stores during the period of evaluation, and those had only been open for a relatively short period of time during their window of evaluation. Anderson et al. (2019) examined a longer time-frame (1993-2017) using the national and state Youth Risk Behavior Survey (YRBS) and reported there was no association between MED laws and past-month prevalence among students; however, they did find evidence suggesting prevalence may have declined for students after REC laws were enacted ([11]). We expect additional analyses will be conducted with these datasets that exploit additional changes in implementation of the state laws, information about per capita outlets and retail sales, and other aspects of the regulatory environments. The results thus far suggest that the mere passage of the laws does not affect youth. More research is needed to understand whether youth consumption is influenced by features of more mature cannabis markets, which are characterised by lower prices, product proliferation, and higher outlet density.

College students

In two studies of college students, D. Kerr et al. (2017, 2018) investigated changes in cannabis prevalence rates after REC enactment in Oregon. In their first study, authors collected responses from online surveys of students (aged 18 to 26) across seven universities, only one of which was in Oregon, between 2012-2016. Using these repeated cross-sectional surveys, authors found that cannabis use rates had increased across six of the seven universities over the time period, but the increase in use rates was significantly greater for students in Oregon that also reported recent heavy alcohol use (Kerr, D. et al., 2017).

In another study using a different repeated cross-sectional survey of university students (ages 18-26) from 2008 to 2016, authors compared changes in self-reported cannabis use rates from two universities in Oregon and 123 universities and colleges from non-REC states. Authors found that, compared to the students in the other states, Oregon students showed a relative increase in rates of past-month cannabis use after REC law passage (odds ratio = 1.29 [1.13, 1.48]) (Kerr, D. et al., 2018).

Adults

W. C. Kerr et al. (2018) analysed self-reported past-year cannabis use in Washington with a repeated cross-sectional random sample of adults aged 18 years and over from before the state implemented REC legislation but after it enacted it (wave 1: January to April 2014) and post implementation (wave 2: March to May 2015; wave 3: August to October 2015). Participants were also asked to recall their past-year cannabis use for the 12 months prior to REC enactment, which started in December 2012. The authors found that respondents reported a small and non-significant increase in past-year use (from 24.3 % to 25.6 %) from the responses relating to the pre-enactment period to the combined average of all three post-enactment/implementation waves (Kerr, W.C. et al., 2018). They go on to state that there was no statistically significant change in the prevalence of the simultaneous use of alcohol. However, the study relies on participants' recall of past-year use, prior to REC law enactment, which may not be accurate and is likely to be influenced by the state's medical cannabis market.

([11]) However, critics have raised concerns about merging national and state-representative samples from the YRBS for conducting analyses of the effects of any state policy, including medical and recreational cannabis laws. Doing so can lead to distortions of the sample in some states, which may affect the results obtained using these data (Jones et al., 2019; Rapoport et al., 2019).

Furthermore, the study does not clearly distinguish between REC enactment and implementation. The null effect reported may be due to the study's design, such as relying on respondents' memory. Without a suitable control group for comparison, it is hard to draw strong inferences.

One cohort study analysed self-reported past-year use data from the repeated cross-sectional National Alcohol Survey of adults across the country between 1984 and 2015. The authors used an age-period-cohort design to assess changes in respondents' past-year use across states that passed REC or MED laws or allowed home cultivation or operational dispensaries. The authors found that the underlying period effects were the main factor contributing to increases in self-reported cannabis use; the passage of REC laws, or laws allowing home cultivation of cannabis and the opening of dispensaries were not significantly associated with increases in prevalence (Kerr, W. C. et al., 2017). They noted that, though REC/MED policies were not associated with changes in prevalence, survey data show a decline in use during the 1980s and 1990s but a sharp increase from 2005 to 2015, varying by demographic and age cohort. The authors attributed recent increases in self-reported prevalence to general period effects that influence the greater population, rather than specific REC policies. Nevertheless, the authors noted that their design does not allow for an analysis of state-specific trends. Furthermore, as their analysis covers a period of more than 30 years, it may be confounded by changes in social attitudes towards cannabis use. They noted that self-reported use may be affected strongly by legal and social norms, which might bias responses.

The previously mentioned NSDUH analysis by Cerdá et al. (2019) looking at cannabis use among youth also examined whether enactment of REC laws influenced the prevalence rates for adults, broken down into two age groups: 18-25 and 26+. Similar to the findings for those under 18, they found no effect on the prevalence rates for cannabis use among those 18-25 after REC enactment; however, the results were different for the oldest group. The authors found that REC enactment was associated with an increase in the prevalence of past-month cannabis use among those aged 26 and over (odds ratio [OR], 1.28; 95 % CI, 1.16-1.40).

While the significant within-state variation in how legalisation is being implemented can complicate state-year panel analyses, it does provide opportunities for learning more about how store density and other factors may influence cannabis prevalence and other outcomes. Merging information about recreational store addresses with location information for adults participating in Washington's Behavioral Risk Factor Surveillance System from 2009-2016, Everson et al. (2019) found that past-month cannabis use 'increased among adults living in areas within 18 miles of a retailer and, especially, within 0.8 miles (odds ratio [OR] = 1.45; 95 % confidence interval [CI] = 1.24, 1.69).' Of course, it would make sense that some stores would try to locate in places with more cannabis users, and the authors attempted to account for this by estimating generalised mixed models with a random intercept by community effect and a random time by community effect as well as controlling for a host of community-level (and individual-level) variables. The authors acknowledge that an important limitation is that the analysis does not account for the number of unlicensed medical cannabis outlets or 'community gardens' operating in the state before and after the REC law was passed; however, they argue this may have biased their results toward zero ([12]).

Finally, one study examined self-reported past-month rates of use in two cohorts of pregnant women and young mothers in an alcohol and drug case management intervention programme before and after REC law enactment and implementation in Washington (comparing wave 1, February 2001 to November 2012, with wave 2, December 2012 to July 2015). The authors compared self-reported past-month cannabis use in samples of participants from nine populous counties in the state and found that women who completed the programme post REC law enactment (in or after December

([12]) Everson et al. note: 'Because we did not account for alternate sources, we overestimated the net proportional increase in cannabis access attributable to the retail market (although not for the law-abiding general public). Our findings may thus underestimate the potential effect of introducing retail access as compared with locations with smaller or less easily accessible medical and illicit markets.'

2012) were significantly more likely to report cannabis use on exit (OR = 2.1, $p < 0.0001$) (Grant et al., 2017). The authors went on to note that women who used cannabis during pregnancy in the post-REC group were significantly less likely to quit than their counterparts in the pre-REC group (33.1 % v 45.4 %, $p < 0.01$). However, the sample of this cohort study limits interpretability to at-risk young mothers and pregnant women attending a drug and alcohol outreach programme and does not include the larger population of young mothers. Furthermore, researchers ignored any different policy impacts between REC enactment and implementation. The reliance on self-reported data may introduce bias in a population of individuals referred to a drug and alcohol abuse intervention programme. The pre-REC population may have under-reported their cannabis use to avoid stigma and legal sanctions.

The mixed results reported in the literature may be, in part, due to the variation in study design methods, sub-population selection and which cannabis policy change researchers are measuring over which time period. As noted, several studies seem to conflate REC law adoption, enactment and implementation. Even when voters approve a REC initiative, it can be one or two years before any cannabis is sold in stores. Along with lags in survey data, researchers, eager to evaluate the impacts of REC, may be incorrectly specifying when a change in policy occurred, particularly given the existing medical cannabis policies that are in place in all of these states that had legalised REC cannabis. Furthermore, the time periods analysed may yield different results. The inclusion of long pre-REC legalisation periods, which pick up the effects of MED cannabis provision, may return different results from studies over shorter pre-REC periods. Finally, studies that combine young people and adults, or at-risk populations and general household populations, may fail to pick up important heterogeneous effects that exist across these populations, as shown in studies examining the effects of medical cannabis policies (Chu, 2014; Pacula et al., 2015; Wen et al., 2015; Smart, 2016).

In Table 4.2 we summarise the main findings of the four articles examining changes in prevalence rates post REC introduction that were discussed above. The remainder of the prevalence studies did not meet our inclusion criteria because of their research design, which lacked a suitable control, or because they were taken from convenience samples, they were cross-sectional or point-in-time measures or they failed to compare pre-REC outcomes with post-REC outcomes.

TABLE 4.2
Summary table of peer-reviewed studies examining the effect of REC laws on cannabis prevalence

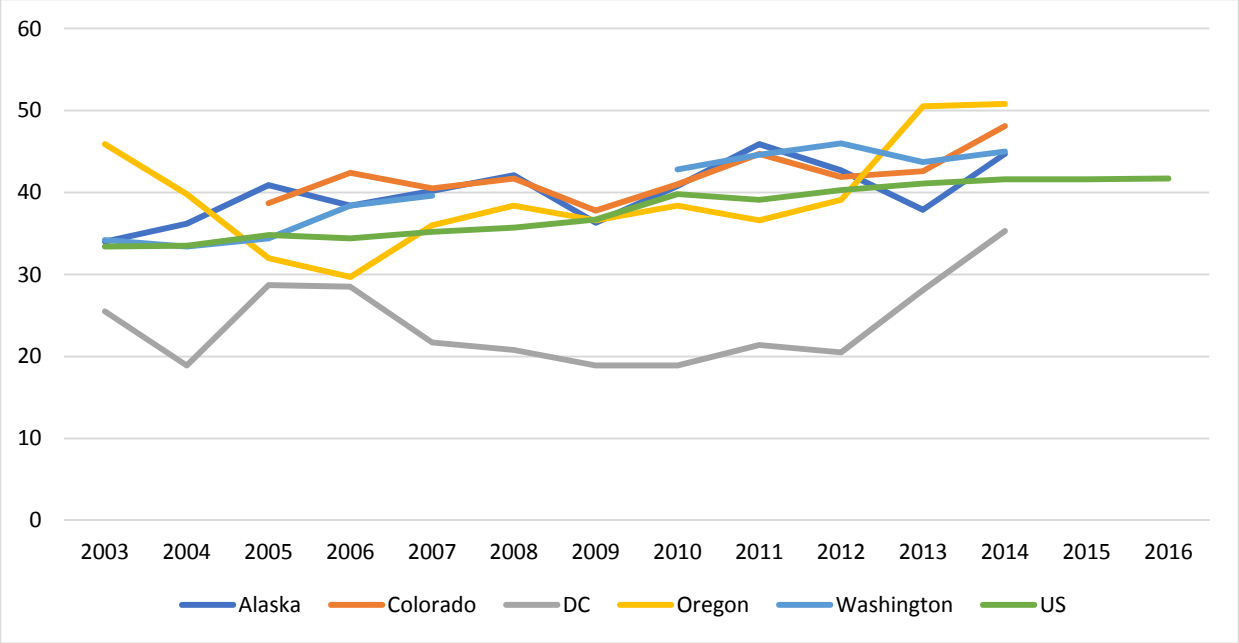
Study	Outcome evaluated	Policy change	Changes associated with policy
Anderson et al. (2019)	Prevalence rates in high school students	REC/MED enactment across states	No change in reported use after MED, possible decline after REC enactment
Cerdá et al. (2017)	Perception of harm and youth prevalence	REC enactment and implementation in Colorado and Washington	Reductions in perception of harm and increases in reported use for 8th and 10th graders in Washington
			No changes in perception or prevalence among 12th graders in Washington or young people in Colorado
Cerdá et al. (2019)	Prevalence rates and self-reported cannabis use disorder rates for youth, young adults, and adults	REC enactment in Colorado, Washington, Alaska and Oregon	No changes in prevalence rates for those ages 18-25. Increase in respondents 26 years or older
Dilley et al. (2019)	Prevalence rates for secondary school students	REC enactment in Washington	Decrease in prevalence rates for 8th and 10th grades
Everson et al. (2019)	Prevalence rates for adults	REC enactment and implementation in Washington	Increase in current use of cannabis for those that reported proximity to a retail outlet
Grant et al. (2017)	Changes in past-month rates of use in pregnant women and young mothers in an alcohol and drug case management programme	REC enactment and implementation in Washington	Significant increases in self-reported use
Kerr, D. et al. (2017)	Prevalence rates in college students	REC enactment in Oregon	No changes in prevalence rates for students in Oregon. An increase in cannabis prevalence rates for those also reporting recent alcohol binge drinking
Kerr, D. et al. (2018)	Prevalence rates in college students	REC enactment in Oregon	Increase in cannabis prevalence rates for students in Oregon
Kerr, W. C. et al. (2017)	Prevalence of adults	REC and MED enactment and implementation	Increases in prevalence are attributed to underlying age-period-cohort factors and not a change in policy
Kerr, W. C. et al. (2018)	Prevalence of adults aged 18 years and over	REC implementation in Washington	No significant change

4.3 Consumption patterns

The implementation of REC laws may affect cannabis consumption patterns in two important ways: mode of administration and intensity of use. Commercial REC provision in the US allows promotion, product innovation and price competition. Each of these factors is expected to shape the way individuals consume the drug — how, where, when and how much. Product innovation allows the substance to be consumed in edibles or vaporised through the use of an electronic cigarette. Improved cultivation methods are shaping the potency of cannabis sold in REC markets, resulting in consumption of higher THC levels and with variations in cannabinoid profiles. The rate and amount of THC that regular users consume is likely to be shaped by changes in price and availability made possible by commercial REC markets.

Nationally, the average number of days of use in the past month reported by past-month users increased from 12.4 to 14.5 between 2003 and 2017 (SAMHSA, 2018). Figure 4.2 displays the percentage of past-month users who reported daily or near-daily use (i.e. > 20 use days in the past month) by state and for the entire country. For the entire country, the rate increased from 33.4 % to 41.7 % between 2003 and 2017. State estimates of daily or near-daily use have not been tabulated beyond 2014, but a similar increasing trend is reported for most states. In 2014, approximately half of past-month users in Colorado and Oregon reported using cannabis on 20 or more days, up from 38 % and 37 %, respectively, in 2009.

FIGURE 4.2
Past-month cannabis users aged 12 years and over using on a daily or near-daily basis (%)



Source: NSDUH

The previously mentioned study by Everson et al. (2019) which exploited variation in recreational store density in Washington state not only found that those who lived within 0.8 miles (1.3 km) of a store were more likely to report use in the past month, they also found that these individuals were much more likely to report daily or near-daily cannabis use.

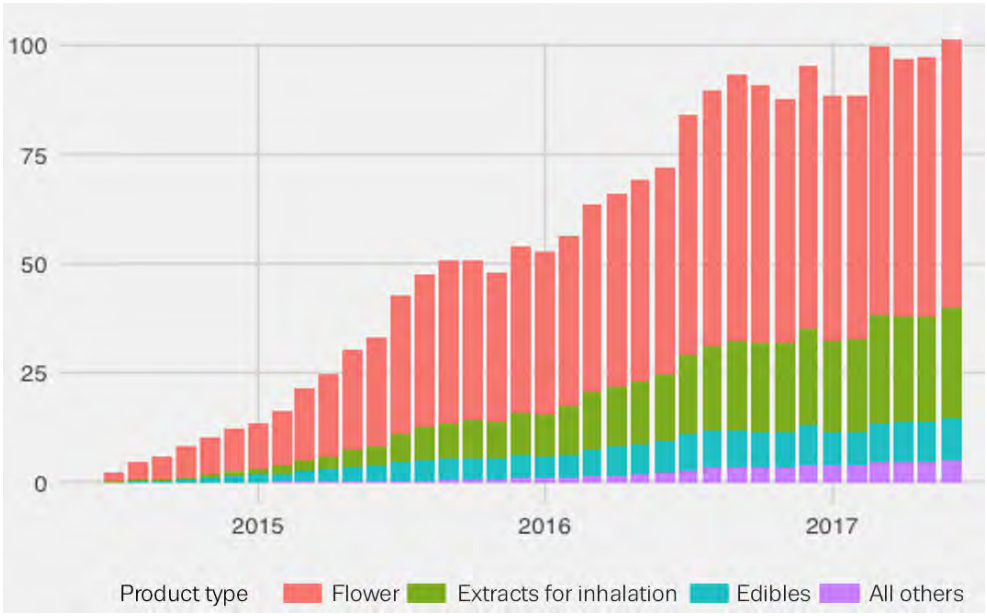
In addition to using individual-level NSDUH data to examine the association of REC enactment with prevalence of cannabis use, Cerdá et al. (2019) also examined the association with frequency of past-month use and past-year cannabis-use disorder (CUD). With respect to frequency of use, they only found a statistically significant increase associated with those aged 26 and older. As for CUD, there appears to be a small and statistically significant increase for youth, but the authors cautioned that they could not rule out that unmeasured time-varying confounders may explain this finding ([13]). But for those aged 26 and over, they report a statistically significant increase in past-year CUD and that there was less concern that unobserved confounding may explain the association.

4.4 Product differentiation and price

As mentioned in the previous section, commercial REC has brought with it product innovation. Such product differentiation and promotion, in turn, shape user behaviour and consumption. Cannabis flower is still the dominant form of cannabis consumed in REC markets, but trends in data collected as part of the seed-to-sale traceability systems in REC states suggest that new products that allow for various modes of administration (vaporising, edibles and topicals) account for an increasing proportion of sales. In one analysis of market trends in Washington, researchers analysed all recorded retail sales (36 million observations) for a little more than two years (July 2014 to September 2016) (Smart et al., 2017). Researchers found that there were important changes in product type, potency and price. Figure 4.3 is an updated reproduction from Smart et al. (2017), showing the

([13]) Specifically, Cerdá et al. (2019) note: 'E-value analyses suggested that unmeasured time-varying confounders hypothetically more prevalent in [REC]states that increase the risk of cannabis use slightly (1.08-1.11 times) may explain this finding. The extent to which such confounders exist is unclear because our difference-in-difference design accounted for unmeasured time-invariant sources of confounding and also adjusted for measured time-varying individual- and state-level demographic characteristics. However, the small E-values warrant a conservative interpretation of the increase in CUD among participants aged 12 to 17 years.'

FIGURE 4.3
Washington's cannabis sales by product type after 37 % excise tax (million USD)



Source: RAND analysis updating Smart et al. (2017)

increasing trend in sales of edibles and vaporisable products, which grew to roughly one third of total sales expenditures by mid-2017.

In terms of potency, an analysis of transaction data (included in the article but not shown here) shows that the reported potency of cannabis flower, as measured by state-accredited laboratories, has increased. The proportion of strains with reported THC concentration greater than 15 % grew to 93 % by September 2016; cannabis flower of less than 10 % THC potency accounted for less than 2 % of expenditures. The authors noted that cannabis flower with more than 20 % reported THC has increased by almost half since October 2014, accounting for 57 % of the retail expenditures (Smart et al., 2017) ([14]). As for price, it is hard to know what consumers would have faced in the absence of REC legalisation but, as predicted, prices are falling. Updated analyses of Smart et al. (2017) and by Davenport (unpublished) show that the average post-tax price for 1 g of cannabis flower fell from roughly USD 20 in October 2014 to USD 10 in October 2015 and USD 7 in October 2017, and it continues to decline ([15]).

A smaller study of MED and REC cannabis users from Washington and Colorado (*n* = 317) and a web-scraping analysis of prices listed on Weedmaps (*n* = 3 802) compared user-reported and dispensary-advertised prices of cannabis in both states during REC enactment periods with prices after implementation (wave 1, October 2013; wave 2, May 2014; wave 3, October 2014). The authors found that there was little price variation in the initial months post REC implementation but that individuals reported paying higher prices for in-store purchases than for social purchases (Hunt and Pacula, 2017). However, the authors noted that a limitation of the study is the very short time period post REC implementation (within five months of stores opening). As noted above, other researchers (Hansen et al., 2017a; Smart et al., 2017; Orens et al., 2018) have shown that prices do decline over

([14]) We note that the potency reported by retailers may not be accurate. For example, initial studies of results from laboratories in Washington show that there are clear systematic differences in potency results across laboratories but that general potency results are inflated (Jikomes and Zoorob, 2018). State regulators have made efforts to address reporting biases.

([15]) Price drops have also been documented in Colorado. A new study by Orens et al. (2018) reports that, from 2014 to 2017, 'the price of one gram of adult use flower exhibited a steady downward trend, decreasing 62.0 percent, from $14.05 to $5.34 per gram' (pre-tax).

long periods of time, providing a strong indication that the immediate effects of these policies may be different from outcomes in the longer term.

Our literature review did find two studies examining the promotion of REC cannabis products, but these were excluded from further analysis, as they did not evaluate trends before and after REC implementation.

4.5 Treatment admissions

It is hypothesised that commercial REC legalisation will change the intensity and frequency with which individuals consume cannabis. This includes consuming cannabis more frequently as well as consuming products with a higher potency. These factors may lead to cannabis use disorder and thus increase the number of treatment admissions. However, it may take years for a cannabis use disorder to develop, suggesting that any immediate changes in admissions may reflect the impacts not of REC legalisation, but perhaps of MED use. At the same time, cannabis possession and use are no longer criminal offences once REC laws have been adopted. Therefore, we would expect reductions in criminal justice referrals to treatment for cannabis after the adoption of REC. A more general point is that treatment admissions data are also influenced by the availability and perceived attractiveness of services and reporting and diagnostic practices, all of which can vary over time. However, no studies investigating changes in treatment admissions were identified during our review.

4.6 Adverse medical events

Under the assumption that REC legalisation increases consumption, a proportion of this type of cannabis use may result in an adverse event (e.g. an overdose that results in an emergency department (ED) visit or hospitalisation) ([16]). Accidental ingestions or overdoses, especially by young children, may result from the supply of certain products, such as edibles that look like traditional sweets. Regulators in Colorado and Washington promulgated emergency regulations to improve labelling and warnings as well as educate the public about the potential effects of new products, some of which are meant to look like benign consumables.

We identified eight articles that looked at changes in various adverse events (such as hospitalisations or ED episodes) before and after (pre and post) MED/REC and their relationship with MED/REC legislation. All articles examine outcomes in Colorado over various periods, some including MED treatment periods. All were pre/post studies without any comparison groups, and may be subject to self-reporting biases (e.g. individuals may be more likely to report cannabis use or seek medical attention post REC). Therefore, caution should be exercised when interpreting their findings.

Significant differences were assessed using standard non-parametric hypothesis testing for all studies. Two of the eight studies examined paediatric or child exposures to cannabis. All of them examined hospital data assessing the impact of changes to Colorado's MED and REC laws. These studies report an increased frequency of adverse events post REC enactment or implementation, and some have observed an increase prior to the adoption of REC, attributing this to lenient MED policies. However, several studies compare different pre and post periods, which in some cases are not immediately before or after the adoption of REC (comparing, for example, per capita rates of events in 2009 and in 2015).

Two studies compared paediatric cannabis exposures necessitating medical attention in Colorado before and after MED or REC implementation. Both studies found statistically significant increases in the frequency of such events following changes in legislation. Wang et al. (2016) report that the rate of cannabis-related visits to the children's hospital increased from 1.2 per 100 000 residents 2 years prior to REC implementation (2012/2013) to 2.3 per 100 000 residents 2 years after (2014/2015)

([16]) An ED visit is recorded when an individual presents to a hospital for emergency care but is not admitted for observation or treatment. A hospitalisation is recorded when a patient is admitted for observation and treatment.

($p = 0.02$). The same study found a fivefold increase in annual poison control ([17]) paediatric cases for cannabis exposures (from nine in 2009 to 47 in 2015) post REC implementation ([18]). This amounted to an average annual increase in calls to Colorado poison control centres for cannabis of 34 %, significantly more than the national average of 19 % ($p < 0.001$). In another retrospective study of cannabis-related ED visits, Wang et al. (2018) found that cannabis-related ED visits increased from 1.8 per 1 000 in 2009 to 4.9 per 1 000 in 2015 ($p = < 0.0001$). Though rates increased, it is hard to say what policy mechanism led to their increase. Cannabis policy in Colorado went through several transformations between 2009 and 2015, including the adoption of several laws and voter initiatives that formalised commercial markets.

Kim and Monte (2016) examined hospitalisation incidents coded for cannabis exposure between 2001 and 2014, collected by the Colorado Hospital Association, to compare before and after MED and REC implementation. The authors found that cannabis-related hospitalisations doubled from 15 per 100 000 between 2001 and 2009 (the pre-MED commercialisation period, when dispensaries were operating) to 28 per 100 000 between 2010 and 2013 (the post-MED commercialisation period) ($p < 0.001$) (Kim and Monte, 2016). The authors noted that this statistically significant doubling occurred after MED implementation. They then examined rates of cannabis-related ED visits between pre- and post-REC implementation, reporting that the figure nearly doubled from 22 per 100 000 (2010-13) to 38 per 100 000 (January-June 2014) ($p < 0.001$).

Using a shorter time period, Kim et al. (2016) examined ED visits for cannabis from 2011 to 2014. The authors reported no significant change from 2011 to 2012 in the rate of ED visits with ICD-9 codes of cannabis use among out-of-state residents, which is possible given that MED is restricted to in-state residents. However, from 2012 to 2014, the state-wide rate among out-of-state residents rose from 78 per 10 000 visits in 2012 to 112 per 10 000 visits in 2013 and 163 per 10 000 visits in 2014 ($p < 0.001$ for all comparisons). Among Colorado residents, the rate of ED visits possibly related to cannabis use per 10 000 visits increased from 61 in 2011 to 101 in 2014 ($p < 0.001$) (Kim et al., 2016). By comparing year-on-year changes, the authors sought to determine the association with changes in REC enactment and implementation. ED data suggest that the rate of adverse events continued to rise over the period, starting in 2011, perhaps because of the expansion of commercial medical markets.

One study looked at annual rates of hospitalisations, ED events and calls to Colorado's poison control centres between 2000 and January to September 2015. Wang et al. (2017) reported that cannabis-related hospitalisations increased from 274 to 593 per 100 000. Examining trends over time, Wang et al. (2017) found a year-on-year increase in cannabis-related hospitalisations over a period starting in 2009 and ending in September 2015. The rates of ED visits also increased year on year, starting in 2011 (the first year for which data were available). The rates of ED visits significantly increased from 2012 to 2013 (358 v 443 per 100 000; $p = 0.003$) and from 2013 to 2014 (443 v 554 per 100 000; $p = 0.0005$). The prevalence of mental illness diagnoses in cannabis-related ED visits was five times higher than the prevalence among those whose ED visits were not cannabis-related, and the equivalent figures for hospitalisations showed a ninefold higher prevalence of mental illness diagnoses among hospitalisations that were cannabis-related. Calls to poison control centres, although flat between 2000 and 2009, increased significantly, from 44 to 93 in 2010 ($p < 0.0001$), and again jumped from 123 to 221 ($p < 0.0001$) between 2014 and 2015 (Wang et al., 2017). The sharp and sustained increase in adverse events began right around the time when MED commercial dispensaries were formalised (around 2010) and continued throughout the adoption and implementation of REC in 2014.

([17]) Calls to poison control centres can be made by patients, the general public or medical professionals. In the US, there are about 2 million exposure calls per year, approximately a quarter of which come from a healthcare facility.

([18]) As a point of reference, Colorado Poison Control reported over 25 000 exposures for those under the age of 19 years between July 2015 and June 2016.

ED visits for cannabis-related mental health diagnoses also increased in Colorado post REC. Similar to Wang et al. (2017), K. E. Hall et al. (2018) reported that, post REC implementation, the prevalence of mental health diagnoses in cannabis-associated ED visits was five times greater than the prevalence in ED visits not related to cannabis (prevalence ratio 5.35, 95 % confidence interval (CI) 5.27 to 5.43). The rate of ED visits in Colorado associated with both cannabis and mental health significantly increased from 224.5 per 100 000 in 2012 to 268.4 per 100 000 in 2014 ($p < 0.0001$) (Hall, K. E. et al., 2018).

In an analysis of ED events in Denver between 2012 and 2015, Sokoya et al. (2018) reported that the number of maxillary and skull base fractures increased post REC implementation (2012-13 v 2014-15) ($p < 0.001$ for both outcomes); however, counts of other facial/cranial fractures were unchanged. Bell et al. (2015) examined cases of burns related to hydrocarbon exposure likely to be related to the home production of butane hash oil extractions from January 2008 to August 2014, before and after Colorado implemented its MED and REClaws. The authors reported no cases prior to MED implementation, 19 cases between October 2009 and December 2013 and 12 cases in 2014, after REC implementation (Bell et al., 2015). Although not reported, the average monthly rate increases from zero in the pre-MED period to 0.37 during MED implementation and to 1.75 per month during REC implementation. Unlicensed extractions using an 'inherently hazardous substance' were subsequently criminalised in Colorado.

Though studies report increases in adverse events, it is possible that some increases could be due to changes in reporting or measurement. For example, it is unclear if increases in ED visits and hospitalisations are due to a greater willingness on the part of individuals to report use of cannabis and/or if doctors are more aware of acute cannabis intoxication post REC and are now more likely to screen for or confirm cannabis use using urinalysis.

4.7 Impaired driving

Changes in cannabis policy may affect impaired driving outcomes (such as accidents or citations for driving under the influence) in multiple ways. While the bulk of the research suggests that driving while under the influence of alcohol is more dangerous than driving under the influence of cannabis, it also suggests that driving under the influence of cannabis is more dangerous than driving sober (Caulkins et al., 2016). It is possible that impaired driving outcomes may change after the implementation of REC, depending on whether cannabis becomes a substitute for or complements alcohol consumption; however, there is mixed evidence as to the relationship. In our review, we identified two studies that evaluated motor vehicle fatalities and one that examined reported insurance claims.

One peer-reviewed study examined the impact of REC on motor vehicle crash fatalities in Washington and Colorado and neighbouring states that did not pass REC but were substantially similar in terms of traffic and roadway characteristics from 2009 to 2015. Researchers analysed changes in the annual number of vehicle fatalities reported in the Fatality Analysis Reporting System (FARS), using a standard difference-in-difference approach with random effects. They then compared four years of pre-REC adoption (2009-12) outcomes with three years of post-REC enactment and implementation outcomes (2013-15). The analysis found no statistically significant difference in fatal crashes between REC and non-REC states (+0.2 fatalities/billion vehicle miles travelled; 95 % CI −0.4 to +0.9) (Aydelotte et al., 2017). However, the authors noted that their policy specification conflates REC enactment and REC cannabis commercialisation, as they used the date the REC law was passed, not the date when stores opened.

A National Bureau of Economic Research working paper (Hansen et al., 2018) employing synthetic controls also assessed the impact of REC on motor vehicle crash fatalities in Washington and Colorado and all states that did not adopt a REC law between 2000 and 2016. The authors found that, between 2013 (the last year before REC implementation) and 2016, drivers testing positive for

THC ([19]) increased in Colorado and Washington by 92 % and 28 %, respectively. However, the authors concluded the following: 'We find the synthetic control groups saw similar changes in marijuana-related, alcohol-related and overall traffic fatality rates despite not legalising recreational marijuana'.

Two more recent studies find evidence of an increase in traffic fatalities after legalisation. In a follow-up study, Aydelotte et al. (2019) added additional years from the FARS database, comparing monthly crash data from 2007 to 2017 in Colorado and Washington, which passed REC laws in 2012, against five other states with MED laws, and four that did not change any cannabis laws. The authors also examined changes in rates after opening of stores in Washington and Colorado in 2014. Aydelotte and colleagues reported that the fatal crash rate in Washington and Colorado increased by 1.2 crashes ($p = 0.087$) per billion vehicle miles travelled after REC enactment, but that there was a statistically significant and larger increase after opening of stores (an increase of 1.8 crashes per billion vehicle miles; $p = 0.02$). The results are sensitive to stores opening, supporting evidence that REC implementation, rather than mere passage, may correlate with outcomes.

In another quasi-experimental analysis, Lane and Hall (2019) examined monthly traffic fatalities between 2009 and 2016 in Colorado, Washington and Oregon compared to nine neighbouring jurisdictions that did not change cannabis laws. Authors specified the opening of dispensaries as the treatment condition instead of REC passage or enactment. They found that store openings were associated with an immediate increase in 1.08 traffic fatalities per million residents followed by a trend reduction of 0.06 fatalities per month (both $p < 0.001$). There was a similar step-up increase and declining trend in both treatment states (step: 0.90, $P < 0.001$; trend: −0.05, $P = 0.007$) and neighbouring jurisdictions (step: 1.15, $P = 0.005$; trend: −0.06, $P = 0.001$). They concluded that:

> *The results suggest that legalizing the sale of cannabis for recreational use can lead to a temporary increase in traffic fatalities in legalizing states that can spill over into neighbouring jurisdictions.*

In another widely cited report, published by the Highway Loss Data Institute, authors compared auto insurance collision claim rates (not necessarily fatalities) in Colorado, Washington and Oregon with those in neighbouring states (Nebraska, Utah, Wyoming, Montana, Idaho and Nevada) that did not adopt REC, from January 2012 to October 2016. The analysis found that collision claim frequencies increased significantly by a combined rate of 2.7 % after REC implementation (Highway Loss Data Institute, 2017).

The mixed results reported in the earlier studies identified are likely to be due to the difference in outcomes evaluated, the specification of the REC policy change or the analytic methods employed. Aydelotte et al. (2017) and Hansen et al. (2018) examined motor vehicle crash fatalities but with different exposure variables (the latter was REC implementation, the former REC enactment); the report by the Highway Loss Data Institute (2017) examined insurance claim data and the relationship with REC implementation. Neither of the motor vehicle fatality studies found a relationship between the fatality rates and REC. However, the report examining insurance claims did find a significant and positive relationship, but one that does not negate findings from other papers. It is possible that non-fatal accidents increased over this period, even if fatal accidents did not.

In the more recent analyses reported here, Aydelotte et al. (2019) and Lane and Hall (2019) examine the relationship with motor vehicle fatalities and the opening of REC dispensaries. Both studies found a positive relationship between opening of stores and motor vehicle deaths. These findings suggest that the appropriate policy change to consider in evaluations is opening of stores, when product becomes commercially available, instead of mere changes in the law.

([19]) However, testing positive for THC is not an appropriate measure for impairment, as THC metabolites may remain in the system long after the subjective and objective effects of intoxication have abated (EMCDDA and CCSA, 2018).

Another possible reason for the inconsistency is the difficulty in identifying impairment at the time of an accident. Current methods reported in traffic fatality and insurance claims data are not sufficient to identify, among drivers who may have consumed cannabis within a specified time period before the accident, those who were actually impaired. Until such technology is developed and widely adopted in current reporting transport databases, we may not be able to sufficiently identify effects from observational data.

4.8 Consumption of other substances

The use of cannabis may substitute for or complement other psychoactive substances. There have been studies examining the relationship between the use of cannabis and alcohol, tobacco or other drugs; however, most of these studies have evaluated the relationship in users of illicit cannabis. REC and MED legalisation may substantially change the relationship or cannabis users' access to other drugs. There are relatively few studies examining the effect of licit cannabis on the use of other substances or associated behaviours. Several studies have examined the population-level outcomes associated with access to medical cannabis. It is important to consider the changes that REC may have on the use of other substances. Social norms and commercial promotion of cannabis may make the use of this drug more appealing to individuals who would have otherwise consumed alcohol in a social setting. Likewise, there is an ongoing discussion in the US on using cannabis as a substitute for riskier opioid analgesics to treat chronic pain (Hall, W. et al., 2018).

Several studies that examined the relationship with cannabis and other drugs are discussed in the table in the Appendix. Yet an extensive and recently published review of this literature by Smart and Pacula (2019) found complex and inconclusive results depending on the substance evaluated and measure used. They concluded:

> *Evidence of the impact of cannabis liberalization on the use of other substances is inconclusive. We have limited evidence of how alcohol or tobacco use has been impacted, and despite a broader literature evaluating the impact of cannabis laws on opioid-related outcomes, the findings from this literature are puzzling. Studies assessing impacts on self-reported misuse and distribution of opioids show no impact of [MED laws], yet studies evaluating opioid-related adverse events and opioid prescribing show reductions. Opioid-related mortality, which early studies suggested was reduced by [MED laws], now appears to be positively correlated with these policies and the adoption of [REC laws]. The significant policy action being taken to combat the opioid crisis as well as the evolution of the types of opioids driving opioid-related harm likely contributes to the lack of robust findings for this outcome.*

4.9 Criminal justice and public nuisance outcomes

The implementation of REC is likely to affect criminal justice and other public nuisance outcomes in multiple and divergent ways. There are concerns about drug-induced crime and disorder, such as acquisitive crime, vagrancy and public consumption. Likewise, REC may alter the broader systemic elements associated with crime, including illicit trade and violence. For example, REC legalisation could potentially lead some illicit distributors to other forms of crime, and unregulated processing that causes explosions pose a public safety hazard; however, we are not aware of any studies examining this. For some of these concerns, it is more than likely that the effects are mixed. For example, police are no longer tasked with enforcing laws prohibiting the possession of cannabis but are now required to stop and detain cannabis-impaired drivers. Some of these criminal justice outcomes are specific to the policy choices found in the US. For example, under federal prohibition, cannabis businesses cannot access the banking system and must deal almost exclusively in cash, making them a target for robberies.

However, there are limits to interpreting law enforcement data. Reports may not be complete or reflective of the change in outcomes. They also may be confounded by changes in policy directives or

attitudes of individual officers. Post REC, public consumption may become more prevalent but under-enforced as the public and law enforcement feel less compelled to intervene in minor infractions. As a result, evaluating counts of public consumption citations may not reflect the true magnitude of violations of the law with regard to using cannabis in public. Many other common 'quality of life' policing tasks are under-enforced. Cities have laws against littering, but these are often arbitrarily enforced by police officers, as this is sometimes seen as a poor use of police time. Likewise, changes in the estimates of intoxicated motorists may be a result not of REC per se but of changes in law enforcement directives and training aimed at detecting impaired driving.

The studies evaluated here report mixed findings. Some suggest that REC is associated with increases in some crimes but unrelated to changes regarding other crimes. This largely depends on the stage at which the policy is evaluated (enactment v implementation) and where. Several studies found that REC is associated with increases in cannabis-specific crimes (e.g. possession, sales) in neighbouring non-REC states, suggesting that individuals may be moving cannabis over state lines.

Using Denver police data on crime reported by census tract, one study compared rates of violent, property and cannabis-related crimes (defined as public consumption, robbery of a cannabis facility, unauthorised distribution, etc.) during MED/REC in Colorado (from January 2013 to October 2015) and examined whether or not they were related to the density of cannabis outlets. Freisthler et al. (2017) reported that the density of cannabis outlets was not associated with property or violent crimes in local areas, but the density of outlets was positively correlated with property crime in spatially adjacent areas over time. Likewise, the density of outlets was associated with higher rates of reported cannabis-specific crime in the same and neighbouring census tract (Freisthler et al., 2017). Nevertheless, this analysis was not able to assess the relationship between unregistered caregiver growers or home growers and incidents of crime. Furthermore, without an interrupted time series and in the absence of controls, authors can only report a correlation with crime and dispensary density. It is also possible that changes in law enforcement capacity and training may have confounded the analysis.

At a more aggregated level, an interrupted time series study examined violent and property crime clearance rates (i.e. rates in which a charge was made for a reported crime) each month from the Federal Bureau of Investigation's (FBI's) uniform crime report data for Colorado and Washington, compared with the US as a whole, from 2010 to 2015. Makin et al. (2018) estimate that REC enactment in Colorado and Washington is associated with increases in police clearance rates for both property and violent crime. This is the appropriate policy indicator, as criminal penalties for possession and use were removed from the penal code on enactment. The authors employ an autoregressive integrated moving average (ARIMA) model to control for seasonality effects in robustness checks, reporting that their findings hold. Without measuring the mechanism of action precisely, they attribute REC enactment to potentially increasing clearance rates by shifting enforcement priorities in the field.

One working paper compared FBI arrest data from the uniform crime report in counties in Washington and Colorado with those in neighbouring states from 2009 to 2014. The authors looked at arrests for driving under the influence (DUIs) and various drug-related offences in relation to REC enactment and implementation (2009-12 v 2013-14). They found that counties bordering Colorado saw an increase of about eight cannabis possession arrests per 100 000 compared with non-bordering counties post REC enactment and implementation; this was greater for counties bordering Washington, which saw an increase of 22.9 arrests per 100 000 compared with non-bordering counties (Hao and Cowan, 2017). Reported arrest rates diminish the further the county is from the state borders of Washington or Colorado, suggesting that cross-state diversion is occurring. However, law enforcement agencies near the border may have shifted enforcement priorities (e.g. targeting out-of-state motorists), potentially confounding such an analysis.

When examining arrests for other drug-related offences (possession of other narcotics, distribution of cannabis or DUIs), the authors reported no association between counties bordering a REC jurisdiction and non-bordering counties post REC enactment and implementation. Nevertheless, the study conflates the REC periods of enactment and implementation. It is more likely that cross-state diversion would have occurred during the implementation period, after stores were opened than immediately following enactment. However, their findings show mixed results. Rates of cannabis possession arrests in counties bordering Colorado increased just prior to enactment in 2012, declined in 2013 and increased again during implementation in 2014. In Washington, arrest rates in neighbouring counties declined prior to enactment in 2012, increased in 2013 and then declined during the first year of implementation in 2014. Such divergence could be explained by the fact that jurisdictions neighbouring Washington have greater access to cannabis, with Oregon adopting a REC law in 2014.

Another working paper examined Washington state recreational cannabis transaction retail data to assess potential interstate trafficking between Washington and Oregon (Hansen et al., 2017b). Washington implemented its REC in July 2014, whereas in neighbouring Oregon stores did not offer recreational cannabis to adults until October 2015. Hansen et al. assessed the impact that REC implementation in Oregon had on sales of cannabis on the Washington side of the border. They also reported that retail sales near the border in Washington declined by 41 % immediately after REC implementation in Oregon (Hansen et al., 2017b). The authors suggest that a substantial amount of demand for cannabis in Washington may have originated in Oregon, resulting in considerable interstate trafficking prior to REC implementation in that state.

4.10 Tax revenues

No studies have evaluated changes in cannabis policy and its impact on *overall* tax revenues (not just those that are associated with cannabis excise taxes and fees); however, state regulators regularly report sales and revenue data post REC. In Table 4.3, we report annual sales revenue and tax receipts. Colorado's figures are for the calendar year (CY) and Washington's are for the fiscal year (FY), which runs from July to June (2016 = July 2015 to June 2016). Retail cannabis sales surpassed a billion dollars in Colorado in 2016 and in Washington in 2017. Sales and tax receipts have increased year on year (with the exception of 2018, for which the information is partial).

TABLE 4.3
Cannabis sales and tax revenue

	Colorado		Washington**	
Year	Sales (CY) (million USD)	Tax receipts (CY) (million USD)	Sales (FY) (million USD)	Tax receipts (FY) (million USD)
2014	683.5	67.6	0	0
2015	995.6	130.4	259.5	64.9
2016	1 307.2	193.6	786.4	185.7
2017	1 507.7	247.4	1 371.9	314.8
2018	1 545.7	266.5	Not reported	362.0
2019*	386.7	63.5	Not reported	Not reported

*January to March for Colorado.

**Recreational only.

Sources: Colorado Department of Revenue, 'Marijuana tax data'; Washington State Liquor and Cannabis Board, Marijuana Dashboard reports sales and tax receipts throughout 2017; Washington State Liquor and Cannabis Board annual report FY 2018 reports total tax receipts for that year.

4.11 Public opinion

Our search found several studies that evaluated public opinion of REC. However, none of them met our inclusion criteria, because they were point-in-time estimates, they failed to include pre-REC measures or they were non-representative. That said, the longest running nationally representative survey asking Americans if they think the 'use of marijuana should be made legal' has shown a steady rise in positive responses since the mid-1990s. In 1996, one out of four Americans supported making the use of cannabis legal. By 2012, support had hit 50 %, and this rose further, to 66 %, in October 2018 (McCarthy, 2018). However, the poll asks about 'use', giving less indication as to respondents' opinions on commercial legalisation. Nonetheless, most commercial legal REC models have been a result of popular voter initiatives.

5. Issues to consider when establishing a comprehensive monitoring and evaluation framework for changes to cannabis regulations

As discussions about cannabis policy intensify (Hughes et al., 2017), policymakers are in a unique position to learn from the experiences of cannabis reform in the Americas. Doing so, of course, requires an understanding of the motives or goals for the policy changes that occurred in that region and the extent to which the policy changes have in fact achieved their stated goals. However, such an understanding can only be achieved through actual measurement of the outcomes associated with these stated goals of the policy reform, both before and after implementation. States in the US that are adopting recreational cannabis laws often argue that such reforms will improve civil liberties and generate tax revenues (Hall and Kozlowski, 2018). There is less emphasis placed on public health and safety goals in the US than in the national discussions in Uruguay and Canada. Researchers note that many jurisdictions have not paid adequate attention to the measurement and monitoring of critical outcomes that are relevant to understanding the impact that REC may have on public health and safety. Without establishing a robust baseline measurement prior to the policy changes, it is difficult to accurately determine the causal impact of such reforms (including unintended consequences) or if they met their intended objectives.

This is perhaps the greatest lesson that policymakers can learn from the early assessments conducted thus far — the need to consider, measure and monitor public health and safety objectives associated with cannabis policy reform before policy changes are implemented. Doing so requires considering all of the potential objectives of cannabis reform that a country may wish to achieve as well as the possible unintended consequences of such changes. Only then is it possible to identify metrics that can be used to assess changes and begin collecting baseline data. Moreover, as discussed in Section 3, many models of cannabis reform are available, and the regulatory model adopted will depend on the specific objectives of the policy change and will also influence the baseline and follow-up data that will be appropriate to assess if the objectives have been achieved.

This section offers insights into creating such a comprehensive framework. We begin with a taxonomy of potential objectives that jurisdictions might seek to achieve (or harms to avoid) with cannabis reform, mapping them to specific outcomes that can be used as metrics for monitoring and evaluation. Since many of these measures are not currently collected, Section 5.2 offers some ideas for creating a data infrastructure to collect them. Section 5.3 offers insights into evaluating changes.

5.1 Potential objectives of cannabis policy change and metrics of evaluation

Discussions of cannabis policy change should begin with a clear understanding of objectives. Table 5.1 provides a taxonomy of potential policy objectives mentioned in jurisdictions that have recently reformed cannabis laws. These are based on communications with policymakers as well as statements made by proponents of ballot initiatives in US states that have recently voted on such initiatives. The stated objectives are to reduce crime and improve civil liberties, to promote public health and to generate economic activity and tax revenues. While not exhaustive, the examples provided in Table 5.1 provide a sense of what might motivate a jurisdiction to reform its cannabis laws and give us the opportunity to consider metrics for measuring the outcome of such a policy change. However, it should be noted that, as illustrated above, the evidence of whether or not these regulatory changes can achieve these outcomes is not yet available.

TABLE 5.1
Statements commonly made by proponents of cannabis law reform

Crime/public safety and civil liberties	Reduce/eliminate the illicit market and related crime
	Re-prioritise law enforcement resources
	Reduce burden on criminal justice system
	Reduce criminalisation of non-violent drug offenders
	Reduce racial or ethnic disparities; correct for injustices of drug prohibition
Health	Make cannabis-based products available for medicinal purposes
	Allow for more research on medicinal benefits
	Reduce youth access and consumption
	Minimise contaminants and ensure product quality
	Offer more information to users on potency and harms
	Improve precision in dosing and potency
	Make it easier to talk about cannabis-related problems
	Reduce use of other potentially more dangerous products (alcohol, opioids)
Prevention	Limit availability by regulating licensees and store operations
Economic/budget	Increase government revenue through taxation and licensing fees
	Reduce cost of prohibition on criminal justice system
	Create new jobs in the legal economy (eliminate illicit market jobs)
Normative	Government should not control what someone puts in their own body
	Prohibition lacks legitimacy

Similarly, a comprehensive evaluation of any policy change must consider the possibility of undesired outcomes. In Table 5.2, we offer a list of statements commonly made by opponents of relaxing cannabis laws.

TABLE 5.2
Statements commonly made by opponents of cannabis law reform

Crime/public safety	Will not decrease, and may possibly increase, illicit market activity
	Burden on law enforcement and public safety
	Increase drug-induced crime, accidents, and negligence Increase in drugged driving
Health	Increase prevalence
	Increase potency, reduce price, and increase access to new products
	Entices youth and new consumers
	Increases addiction and substance use disorder
	Encourages experimentation and use of other drugs
	Normalises drug use, potentially re-normalisation of tobacco use
Prevention	Makes prevention campaigns ineffective
Economic/budget	Increases costs to state
	Reduces productivity
Normative	Sends the wrong message
	Incompatible with international treaties

Table 5.3 lists some potential metrics that could be used for monitoring and evaluating the impacts of cannabis legalisation on particular policy objectives. This list is based on the studies listed in Section 4 as well as our own experiences evaluating other cannabis policy changes. It also builds on some of the suggestions offered in Kilmer and Pacula (2017). In the table, we have placed these items into four general categories that are not mutually exclusive ([20]): health, crime and criminal justice, economics and other. We are not aware of any country that collects all the variables listed in the table, and it is likely that additional variables of importance are missing.

TABLE 5.3
Variables for monitoring implementation and evaluating changes in cannabis policy

Variables	Sources for obtaining these data	Implications for evaluating policies
HEALTH		
Prevalence	General population surveys (GPS), school surveys, medical surveys	Adult annual and 30-day prevalence rates are expected to increase with cannabis liberalisation; however, the health implications of this are unclear, as simple increases in prevalence rates indicate nothing about the potential health risks associated with consumption. More information about frequency of use, mode of administration and product consumed is needed to fully understand the potential health impacts of the changes in prevalence rates. The effect of legalisation on youth prevalence rates is ambiguous. The rates could increase, as we expect they will with adults, but they could decrease (1) if the regulated market makes it harder for young people to access cannabis and/or (2) if there is a forbidden fruit effect (MacCoun, 1993). These effects may also offset one another.
Frequency	GPS, school surveys, medical surveys	If cannabis liberalisation policies increase frequency of use — especially daily/near-daily use — then there are greater potential health effects. Specific health risks depend on the demographics of the user group (young people v adults, pregnant women or other at-risk users), the amount consumed per dose, the potency and the cannabinoid profile of the products consumed, and the method of ingestion — all of which will influence the actual health risk.
Cannabis use disorder (CUD)	GPS or school surveys; voluntary treatment, and ED and hospital admissions; qualitative interviews with selective populations — all of these sources capture a subset (sometimes overlapping) of people with CUD For duration, longitudinal studies would be strongly preferred, but it may be possible to get some of this information from retrospective surveys.	The rates of CUD might rise or fall with cannabis liberalisation, depending on what happens to heavy use and treatment admissions. On the one hand, a decrease in criminal justice referrals could reduce the probability of someone with CUD receiving treatment. On the other hand, legalisation may make it easier for those with CUD to talk openly about their problems and obtain help.
Products used	GPS, school surveys, medical surveys, traceability data and qualitative surveys of key user groups	There are different risks associated with different types of cannabis products. Some adverse health events are tied directly to acute overconsumption of THC, while other longer term health effects are related to the method of administration (i.e. the long-term effects of smoke on the respiratory system). As a result, information on the products used will be useful for thinking about the potential health consequences observable among the population.

([20]) For example, traffic accidents could be included in either health or crime.

Variables	Sources for obtaining these data	Implications for evaluating policies
Amount consumed	Questions about the amount of cannabis consumed may be included in GPS or school surveys as well as medical surveys. Some web-based surveys ask about the amount consumed and use picture prompts to help guide respondents. In such cases, respondents are randomly shown a photo of different amounts of cannabis and asked to quantify how much they think each amount weighs. This improves researchers' understanding of the amount of cannabis consumed. Capturing the potency of the product (actual or perceived) is also useful but may best be obtained through qualitative interviews with selective populations.	The amount consumed per day or per episode of use is important for understanding (1) the risk of an acute harm and (2) the risk of developing a CUD. Ideally, it would be preferable to move beyond grams of herbal cannabis or puffs from a vape pen towards collecting information about the consumption of THC and other chemicals in the cannabis plant.
Prevalence and consumption of other substances	GPS, school surveys, medical surveys; treatment admissions; hospital and ED admissions; and qualitative studies of key user groups	The net effects of cannabis liberalisation on public health depend on whether cannabis becomes a substitute for or complements other potentially harmful substances. For example, if cannabis is used most often with tobacco (i.e. they are 'complements'), then cannabis legalisation might hamper efforts to reduce tobacco use. If cannabis and alcohol are substitutes, then having users switch from alcohol to cannabis might generate net health gains (e.g. reduced accidents, reduced domestic violence, reduced liver cirrhosis). If cannabis and alcohol are complements, then some health risks may be made worse with cannabis liberalisation policies (e.g. accident risk, heart risk). Thus, it is important to understand if liberalisation policies lead to the use of cannabis in lieu of other substances (tobacco, alcohol, opioids, new synthetic cannabinoid agonists) or to joint consumption. This might differ among different segments of the population.
Other mental health disorders	GPS, school surveys, medical surveys; longitudinal surveys; treatment admissions; hospital and ED admissions; qualitative studies involving key populations	Even if cannabis use does not directly cause mental health disorders but simply increases the likelihood of onset at an earlier age, cannabis liberalisation policies may still increase the prevalence of some mental health disorders (psychoses, schizophrenia, etc.). The correlation may depend on the typical amount consumed, frequency of use and THC exposure.
Treatment admissions	Treatment facilities; healthcare systems; GPS surveys; qualitative studies on selective populations Possibly from government healthcare records	If cannabis liberalisation policies lead to an increase in consumption such that they increase the prevalence of CUD, it is possible that a jurisdiction will see a rise in cannabis-related treatment admissions. However, if treatment referrals for cannabis come largely through the criminal justice system, then legalisation may lead to an overall decline in treatment admissions.
Hospitalisations and ED visits	Hospital databases; insurance claims	ED visits and hospitalisations may emerge from one of three potential mechanisms: (1) immediate unexpected reactions to cannabis products consumed by naive users (e.g. accidental poisoning from edibles); (2) risky modes of consumption (e.g. dabbing) or behaviours while intoxicated (e.g. driving); and (3) longer term health problems aggravated by prolonged cannabis use, particularly in certain forms of products (e.g. respiratory issues from smoking).
Calls to poison control centres	Poison control centres; emergency service calls	Calls to poison control centres typically result from overexposure to THC, which most frequently occurs through the overconsumption of edibles (multiple standardised doses) or exposure to high-potency products.

Variables	Sources for obtaining these data	Implications for evaluating policies
Education and employment outcomes	GPS or school surveys; longitudinal surveys; education and employment agencies; standardised testing results in secondary schools or for graduation; graduation rates; employee drug testing data	Absenteeism and presenteeism are both potentially affected by increases in cannabis use, particularly if cannabis is consumed prior to or during work or school. Such behaviour could ultimately influence longer term productivity and tax revenues of the government. Tracking changes in education and employment outcomes before and after the adoption of a change in cannabis policy can help identify the need for additional workplace/school policies or targeted messaging regarding appropriate use.
CRIME AND CRIMINAL JUSTICE		
Cannabis-related arrests and seizures	Police statistics	The legalisation of cannabis should generate a net decrease in the number of arrests and seizures, but these will not fall to zero for at least two reasons: (1) most jurisdictions retain the prohibition of use/purchases by young people and (2) illicit markets may persist for some time after a policy change. Information on arrests can provide insights into criminal justice savings associated with legalisation, while seizure data can provide some insight into profit motives for the illicit market to remain (e.g. specific products not available in the legal market, or specific populations unable to participate). Nevertheless, law enforcement data may be biased because of internal policy directives and changes in resources, agency capacity and citizen reports. Caution should be used when evaluating these data.
Cannabis-related police-citizen contacts	Perhaps police databases — new record keeping may be required After legalisation, civilians could also track consumption in public spaces	Enforcing new regulations adopted by a jurisdiction around legal cannabis will require resources, so tracking information on cannabis-related police contacts (including those that simply lead to confiscation) is important for accurately understanding the net budgetary impacts on crime and public safety resources. This information can also be useful for understanding how changes in cannabis laws affect racial/ethnic disparities in criminal justice outcomes.
Unregulated cannabis processing involved in explosions	Police or public safety statistics	Though some individuals may already be processing illicit cannabis flower and turning it into concentrates, the legalisation of cannabis might encourage more people to extract cannabinoids from dried plant matter using volatile chemicals and solvents. Unsafe processing practices may pose a public safety hazard should the volatile chemicals combust.
Penalties for cannabis offences	Court records; corrections agencies, police databases	In the US, arguments have been made that cannabis legalisation will improve civil liberties, reduce racial disparities in the criminal justice system and improve police-community relations. Monitoring how the criminal justice system responds to changes in the law will allow us to evaluate these arguments.
Criminal justice spending on enforcing cannabis laws	Police databases; court records; corrections agencies; regulatory agency data (compliance checks, citations, fines)	As previously stated, the enforcement of new regulations adopted within a jurisdiction will require some criminal justice resources, particularly if some violations of the new regime still involve criminal penalties. Tracking this information is necessary for understanding the cost of enforcing the new policy and net criminal justice savings.
Self-reported impaired driving (or travelling with someone who is impaired)	GPS, school surveys, medical surveys; could be added to treatment intake surveys	This is one of the most likely infractions to arise in response to the legalisation of cannabis within a jurisdiction, although the rate of increase depends on a variety of factors, including a jurisdiction's reliance on cars, the deterrent effect from law enforcement and the effectiveness of prevention campaigns to promote sober driving/responsible use. However, not all impaired driving will be detected, so, given limited policing resources, these data will be useful for understanding which groups are likely to drive under the influence of drugs and where and at what times such behaviour is likely to occur.

Variables	Sources for obtaining these data	Implications for evaluating policies
DUI prosecutions	Police statistics; insurance claim data; qualitative data collection in particular areas	DUI arrests and prosecutions are a function of (1) the amount of impaired driving and (2) the level of enforcement. Higher DUI arrests without additional enforcement suggest a rise in impaired driving and the need for additional messages to be targeted at at-risk users. It also raises the criminal justice costs associated with legalisation. However, total DUI arrests might fall with a change in policy if cannabis becomes a substitute for alcohol. Thus, information on DUI arrests (for alcohol, cannabis and other substances if available) can help inform the jurisdiction about how cannabis is being used by specific segments of the population. Nevertheless, changes in enforcement priorities and training may confound analyses that use law enforcement data.
Traffic crashes or fatalities	Transport and insurance claims databases	Changes in traffic crashes and fatalities may indicate a change in impaired driving that is not reflected in arrest statistics. Objective analyses will focus on the total number of crashes/fatalities, not just those in which the driver tested positive for THC. This can offer a better understanding regarding the potential substitution of cannabis for alcohol or their concurrent use.
Arrests/convictions for other crimes	Police databases; court records	Tracking changes in arrests/convictions for other crimes helps to identify the public safety benefits/costs associated with legalisation — in so far as arrests reflect changes in crime patterns (that may be associated with use of cannabis and/or its substitutes or complements). Nevertheless, changes in enforcement priorities and training may confound analyses that use law enforcement data.
Calls to emergency services	Police databases, possibly other government agencies	Since not all crimes result in an arrest, tracking information from calls to emergency services may identify changes in the need for law enforcement intervention because of a change in the consumption of cannabis and/or its substitutes and complements.
Victimisation surveys	Victimisation surveys; medical reports	Information on the changes in victimisation with the legalisation of cannabis is relevant for considering public safety impacts. Again, it is unclear if victimisation would rise or decline with legalisation; much will depend on how the policy change affects the use of other substances.
ECONOMICS		
Total expenditures on purchasing cannabis products	GPS; retail sales (medical or other outlets); combining consumption estimates from wastewater testing with THC price estimates	Information on cannabis expenditure serves at least three purposes: (1) it helps identify tax evasion, particularly if taxes are tied to the amount sold; (2) it is helpful for understanding which products are sold (by form and potency if information is collected by product); and (3) it is useful for constructing an estimate of the total size of the cannabis market (demand based), which can then be used as a way of measuring the impact of further policy refinements on the market.
Source of cannabis supply	GPS; web surveys of heavy users	Information on the source of cannabis is very helpful for understanding the extent to which the legal market is able to replace the illicit market.
Amount of cannabis produced in the legal market	Traceability systems; visual inspections	Traceability systems are valuable for a range of regulatory purposes in a legal cannabis market, including (1) measuring the total amount supplied to a market (which, when combined with a demand estimate, can identify the presence and size of an illicit market); (2) projecting estimates of tax revenue from sales (which can then be compared with actual tax revenue to help identify tax evasion); and (3) identifying and tracking products sold, which is useful for understanding the potential health risks that consumers might face (this is relevant to prevention messaging as well as the issuing of product recalls).

Variables	Sources for obtaining these data	Implications for evaluating policies
Prices	GPS, medical surveys, arrestee surveys; web surveys of heavy users; menu analyses; traceability systems; law enforcement sources; crowdsourcing websites such as 'Price of Weed'	Prices are important, because they can influence many of the outcomes that are discussed in cannabis policy debates: size of the illicit market, tax receipts, business revenues and consumption.
Presence of retail establishments	Regulatory agency overseeing cannabis legalisation; local government zoning boards	The illicit market for cannabis can be reduced if there is a licensing system identifying legitimate sellers from illegal sellers. Enforcement against illegal sellers is a necessary component of a licensed system. However, the density of retail establishments can also influence the perceived availability (changing norms about the substance) and can reduce the effectiveness of prevention programmes aimed at reducing use among particular groups. The regulation of retail establishments will be a cost of legalisation, affecting net revenues from a change in policy. More retail establishments increase the number of entities that need to be policed (and hence the cost of doing so).
Licit sales and tax revenues	Regulatory agency overseeing cannabis legalisation; other government agencies	Tracking sales and tax revenue is important for measuring the size of the market and whether or not tax revenue is growing. These taxes are often earmarked for prevention efforts, regulatory oversight and other costs imposed by users on society.
Employment in the cannabis industry and other related industries	Could try to deduce this from total production estimates and qualitative methods pre legalisation; after legalisation, it should be part of regular labour statistics	Information on employment in the cannabis industry can indicate the economic value of the industry to a community. It also provides insights into the relative importance of this industry vis-à-vis other industries in an area. Of course, legalisation can affect other segments of the economy, besides those directly involved in the cannabis trade.
Cost of regulation and law enforcement	Regulatory agencies overseeing cannabis legalisation; police databases; court records; corrections	While there are likely to be criminal justice savings associated with cannabis legalisation, there are also agency costs associated with regulating a new business. The economic impact of legalisation is a function of the jobs and tax revenue that comes with the new market minus the cost of regulation and law enforcement monitoring and regulating the new market. This information is vital for a proper estimation of the net economic impact of legalisation.
OTHERS		
Consumer characteristics	Administrative or regulatory data; qualitative studies of key target populations	Jurisdictions that collect information on patients or registered adults (e.g. Uruguay) may allow for a further understanding of the user base. This could include descriptive information on patient ailments or demographic information regarding a typical registrant and how much they purchase over the course of a year.
Public support	Public opinion polls	These polls provide a source for evaluating the normative justification for a change in cannabis policy.
Advertising/promotion	Could require all cannabis advertisements be reported to regulatory agencies; could also conduct studies by the European Medicines Agency	The degree to which cannabis products are advertised and promoted might influence the type and amount of prevention material needed by a community to reduce the potential harms associated with legalisation.

5.2 Establishing the data infrastructure

Once a jurisdiction has identified the objectives for considering a policy change as well as specific metrics that would be useful for monitoring impacts, it can then consider appropriate data collection. The second column of Table 5.3 offers ideas for collecting or generating relevant data. Keep in mind that there are strengths and weaknesses of different data sources and various approaches. In this section, we discuss in greater detail some of the issues to consider when relying on some of these sources.

General population surveys (GPS) and student surveys

GPS and student surveys will be useful for some of these items, but care must be taken when using these data to draw inferences about cannabis policy changes, for several reasons. Most importantly, there is strong evidence suggesting that survey respondents under-report the prevalence of drug use in GPS (e.g. Harrison et al., 2007). While many studies have relied on assumptions that under-reporting — although unknown — is fairly stable year on year, these assumptions will not necessarily hold if a policy changes. For example, if a policy change reduces the stigma around admitting cannabis use, then more people will be willing to honestly report their prior behaviour, making it hard to identify the extent to which any change detected is attributable to a true increase in cannabis use as opposed to more honest reporting, or both.

One way to assess the degree to which under-reporting might exist and change with policy would be to validate the GPS with a biological test (e.g. saliva tests or urinalysis), to determine the proportion of respondents who are misreporting at a given point in time. This has been done in the US, but we are not aware of any attempts to do this in Europe (Kilmer et al., 2015). Another alternative that might be considered is to incorporate the use of the randomised response technique for key estimates into the questionnaires (Blair et al., 2015). Such validation does not have to be done every year, but doing it now and possibly a few years after a significant policy change would provide extremely useful information about baseline rates of under-reporting and how these change over time. The use of wastewater epidemiology may potentially generate useful confirmatory measures for cannabis prevalence rates (Zuccato et al., 2008). Countries in Europe and elsewhere may not want to rely on US under-reporting estimates from nearly 20 years ago to inform these adjustments.

There are also some questions that could be added to GPS regarding consumption and expenditure that would improve our understanding of these markets and how they could change (e.g. asking about the types of cannabis products used and the amount consumed). Adding questions about market transactions is critical for understanding expenditures and revenues generated by illicit suppliers, which is important if the goal is to understand the impact of policy changes on the size of the illicit market. Since it may not be possible to add an entire cannabis market module, as was done in the US from 2002 to 2014 (and reinstated in 2018), adding two questions concerning (1) the amount spent during the last purchase and (2) the number of purchases in the previous month would be enough to provide the foundation for market estimates.

It would also be helpful to collect information about the types of products purchased. Information on the types of products is especially valuable if a jurisdiction decides to limit the legal sale of cannabis to particular forms (e.g. herbal cannabis), which Uruguay does. Responses can indicate if individuals are sourcing other products (e.g. edibles) from illicit markets.

Web surveys

While it is possible to use internet-based surveys with strong sampling frames to generate population-representative inferences about cannabis use and purchasing patterns (e.g. Pacula et al., 2016), many of the web surveys about cannabis fielded in Europe and the US are convenience samples (e.g. Kilmer et al., 2013; van Laar et al., 2013; Matias et al., 2019). While these relatively inexpensive surveys do not allow for precise estimates about a representative sample, they can provide plausible ranges for key variables if the samples are large enough. If targeted correctly, they can help provide information about heavy users, who may be less likely to be included in the sampling frame for GPS or student surveys but account for the largest part of consumption and expenditures (Kilmer et al., 2014).

Indeed, combining estimates from GPS and web surveys is becoming an increasingly popular approach to generating market estimates for consumption and expenditures. Typically, the GPS estimates of the number of use days are combined with the web survey estimates of the amount consumed per use day for various types of users (e.g. weekly, daily/near daily). In some cases, these estimates are generated only for an entire country (e.g. Caulkins and Kilmer, 2013), while other

studies generate these estimates for specific age or gender groups and then add them together to generate an aggregate estimate (e.g. Caulkins et al., under review; van Laar et al., 2013). Another approach to using unrepresentative web surveys to generate population-wide estimates is to use a raking algorithm to reweight web survey respondents to match GPS data (see Caulkins et al., 2019).

Cannabis medical surveys

In the light of the changes happening within US jurisdictions, several health insurers are beginning to elicit information about cannabis use (both medicinal and recreational) in their regular patient surveys so as to monitor use of the substance in a fashion similar to alcohol and tobacco. While this information is not publicly available from private insurers, it could easily be collected by public insurers in various jurisdictions. Distinguishing medicinal consumption from recreational consumption would be key, as the particular forms of cannabis, the amounts consumed and frequency of use are likely to differ, depending on the subpopulation considered (Pacula et al., 2016; Lankenau et al., 2017).

Cannabis tracking systems

In the shadow of federal prohibition, states that passed legalisation have implemented 'seed-to-sale' traceability systems to signal that they are taking the issue of diversion seriously. These systems track every plant throughout the supply chain, ending at retail sale. They can include information about the prices paid by processors and retailers as well as information about cannabinoid content and the types of products sold on the licit market. While these systems were not necessarily designed for research purposes, they are being used by an increasing number of researchers to help understand the markets and other cannabis-derived products (Smart et al., 2017), to estimate the price elasticity of demand (Hansen et al., 2017) and the level of competition in the market at the wholesale and retail levels (Caulkins et al., 2018).

In the US, there are no systems to track sales made to specific individuals (i.e. the identities of purchasers is not tracked), but there are in Uruguay. In addition to a seed-to-sale system, Uruguay tracks and limits purchases by individuals. Retail purchases can be made only at participating pharmacies and are limited at 40 g/person/month. To make sure individuals do not exceed these limits, a biometric system requires registered buyers to submit a thumbprint before making a purchase (Miroff, 2017). The pharmacy receives immediate feedback from the government database about whether or not the person has exceeded the allowable retail transaction limit; if not, the sale is made. The total weights and numbers of sales per location are then reported to the national monitoring agency.

Other countries considering changes in cannabis policy are not constrained in the same way as the states in the US, and may want to limit the amount of cannabis that can be purchased in a given time period, or consider implementing seed-to-sale systems to obtain data that are relevant to other policy objectives, including identifying leakages to the illicit market, contaminated products for recalls and valuable information regarding the types (and amount) of various products sold. This information can be important for monitoring compliance and providing information for economic and other analyses. Such information will allow regulators and researchers to triangulate with other indicators, such as self-reported user behaviours from population surveys.

5.3 Thinking seriously about outcome evaluations

The third column of Table 5.3 provides an explanation for why particular types of data are useful for generating inputs that can be used to measure many outcomes of interest, including (1) the actual demand for cannabis in a market; (2) the size of the legal cannabis supply and industry; (3) the size of the illicit market supply of cannabis; (4) the net impact of cannabis legalisation on the criminal justice system (arrests), the public safety system (calls to emergency services, victimisation) and the health system (hospitals, poison control centre calls, accidents); and (5) the net economic impact of the market on the government in terms of jobs created, tax revenue, regulatory costs and health/law enforcement net costs (or savings). It is worth mentioning that this report and many evaluations of

REC to date exclude any evaluation of the benefits — including mere pleasure — of legal cannabis reforms. It is difficult to assess these consequences, as they are often subjective and difficult to quantify, but any serious evaluation of these legal changes ought to consider these outcomes (Caulkins et al., 2016).

Collecting the appropriate outcome data is necessary but insufficient for evaluating these policy changes. Serious thought must be given to defining precisely what is evaluated and what is the counterfactual, to allow the determination of causal inference about policy change. This section addresses some of the issues for those considering an evaluation.

Understanding the cannabis market and expected sanction for a cannabis violation *before* the policy change

There are a number of mechanisms that may influence cannabis use after a policy change, such as stigma, price, promotion, availability, expected sanction and the 'forbidden fruit' effect (MacCoun, 1993). Collecting the baseline data for price and expected sanction is important for understanding not only the casual mechanisms at play but also how different forms of legalisation may have different effects on use and other outcomes. For example, if a jurisdiction that does not criminally sanction cannabis possession chooses to legalise the supply of cannabis, the criminal justice cost savings of doing so will not be as great as a jurisdiction that criminally sanctions cannabis users. Alternatively, if a government implements a regulatory regime that keeps the price per unit of THC similar to its pre-legalisation price, it may not detect as much of an effect on use compared with other regimes that have experienced price declines as a result of market competition (Kilmer et al., 2010).

Collecting market information (e.g. information on prices, products, promotion, the number of outlets) is important, especially for jurisdictions that had vibrant commercial medical markets before recreational legalisation. It could also be useful in countries such as Spain, where, despite national prohibition, significant numbers of cannabis social clubs are tolerated in some regions, some of which may become increasingly commercialised (Pardal, 2018).

Canada has made an effort to obtain baseline data for future evaluations. For example, building on the Canadian Student Tobacco, Alcohol and Drugs Survey, Health Canada designed the Canadian Cannabis Survey, aimed at understanding the pre-legalisation cannabis market. In 2017, the national government fielded the phone-initiated survey designed to obtain a sufficient representation among key population groups across all provinces and territories. The survey not only included questions that are relevant to cannabis consumption but asked respondents about their purchasing habits (how much they bought, how often, from what sources and at what prices). The findings informed discussions on the cannabis law and will also be used to evaluate its implementation in the future (examining changes in prevalence, price, frequency of use, etc.). In addition, Public Safety Canada commissioned work to estimate the price of cannabis throughout the country (Ouellet et al., 2017), and Statistics Canada created a 'Cannabis Stats Hub', which has many similarities to the EMCDDA's Statistical Bulletin but includes more detailed information about the cannabis economy.

Considering the counterfactual and underlying context

Section 4 highlights the growing number of studies recreational legalisation in the US that include a control group, but much attention is still paid to simple pre-post analyses of trend data (for more on trends, see Appendix C). While cross-jurisdictional comparisons seem like an obvious approach to applying rigorous research methods to learn about these policy changes, caution must be exercised, as important differences in definitions, survey methodologies, the frequency of data collection and other factors can limit inferences from these exercises (MacCoun, 1993; Kilmer et al., 2015; Giommoni et al., 2017). More importantly, the assumption that any single jurisdiction adopts a uniform policy, which is required and embedded in many cross-national studies, is clearly problematic (e.g. states in the US vary considerably in terms of their cannabis regulations and enforcement). Similarly, context matters. Different jurisdictions may have different starting points for the adoption of REC. This may be less of a transition for a jurisdiction with a robust medical cannabis market or some social

access (e.g. the Dutch coffee shops or cannabis social clubs in Spain) than for a jurisdiction that aggressively enforces cannabis prohibition.

Another approach is to take advantage of within-state variation in how policy is being implemented. For example, although the states of Colorado and Washington passed legalisation in 2012, there are still a number of localities in these states that do not allow retail stores. This has allowed researchers to exploit the variations in retail cannabis outlet density to learn more about the effect of commercialisation (e.g. Dilley et al., 2017). Similarly, studies exploiting variations in medical cannabis access within California have been carried out to examine the impacts on use, hospitalisation and crime (e.g. Mair et al., 2015; Freisthler et al., 2016; Hunt et al., 2018). An advantage of using intra-state variation is that there is less concern about data comparability and policy comparability, and there may be shorter time lags. Of course, there may be important issues of policy endogeneity that will need to be considered in the statistical models (Pacula and Smart, 2017).

Paying close attention to dates and isolating policy exposure

The date used to denote when the policy change occurred obviously has important implications for the results of outcome analyses. There can be not only lags between the date of passage and the date the policy goes into effect but also important lags between passage and the ability to purchase cannabis from a store, as it can take time to build a regulatory system. For example, the voters in Colorado and Washington passed legalisation in November 2012, but the recreational stores did not open until January 2014 and July 2014, respectively ([21]). Thus, outcome analyses of legalisation that use dates when laws were passed, rather than when stores opened (or when a majority of the adult population had access to cannabis), are at serious risk of drawing the wrong conclusions if changes are driven principally by market activity and not shifts in norms (Pacula and Smart, 2017). The dates can also be useful for learning more about the causal mechanisms underlying possible changes in use (e.g. the period when it is legal to use or possess but before the stores have opened) and understanding the short- and long-term implications of these policies.

It is imperative that when regulatory changes are introduced, governments, or possibly agencies such as the EMCDDA, document what the legal changes allow/require and whether or not local variation is permitted (e.g. if shops allowed). Although this seems obvious, it can be difficult to obtain this information, as enacted laws may not include regulatory details that can influence outcomes of interest (e.g. testing requirements). Better-prepared jurisdictions will require regulatory agencies to publicly document this information and note when changes are made to regulations. This type of documentation is especially important if the new policy allows local variation.

Acknowledging that the short- and long-term effects of legalisation could be different

It is entirely possible that the short-term effects of a policy change differ from the long-term effects. This is likely to be true, as knowledge about products and how they might be used (or misused) takes time to develop, as do changes in social norms concerning the appropriate (or inappropriate) use of the products. Even existing markets can see the introduction of new products (e.g. hash oils and concentrates) that capture different properties of the original cannabis plant (e.g. higher THC content) and which can also change the known health impacts of the substance. It is certainly the case that we have very little knowledge of the health implications of the products currently sold in US legal markets (e.g. Kilmer, 2018). Most of the research on the health benefits and consequences of cannabis are based on cannabis plant material with far lower THC and higher CBD concentration levels than those observed on the legal market in the US today. Thus, it is difficult to infer the long-term effects of these newer, less researched, products.

([21]) Even though some stores opened in Washington in July 2014, it was some time before most of the licensed stores opened and had enough inventory to push prices below the pre-legalisation levels.

6. Concluding thoughts

This document is intended to inform discussions about the value of having tools in place to evaluate the impact of any major changes to the regulatory approach to cannabis used. By highlighting the various approaches unfolding in the Americas and some of the emerging evidence from states in the US, namely Colorado and Washington, we construct an analytic framework and empirical foundation that we hope will contribute to productive and dispassionate policy discussions.

We cannot stress enough that the peer-reviewed literature review on legalisation of adult cannabis use is nascent, and that results are likely to be conflicting, depending on which data and methods are used as well as which policies are evaluated. It is important to remain sceptical of early studies, especially those that use a simple binary variable to classify legalisation and non-legalisation states. This scepticism should extend to the many studies that fail to account for the existence of robust commercial medical cannabis markets that predate recreational cannabis laws. Even if a consensus develops on certain outcomes, this does not mean that that relationship will hold over time. Changes in norms concerning cannabis use and potentially other substances, the maturation of markets and the power of private businesses (if allowed) could lead to very different outcomes 15 or 25 years after recreational cannabis laws have been passed. Evaluations of these changes must be considered an ongoing exercise, not something that should happen in the short term.

Insights from evaluations of possible supply changes in Europe will depend on the number of data collected before the change; simply comparing past-month prevalence rates will not tell us much about the effect of the change on health. While US jurisdictions have been moving quickly to legalise cannabis, the data infrastructure for evaluating these changes is limited. In contrast, Canada has made important efforts to field new surveys and create new data collection programmes in anticipation of legal changes. If some jurisdictions are considering a major adjustment to cannabis supply policies in the near future, then it is prudent to start thinking as soon as possible about improving data collection and analysis systems to support subsequent evaluation exercises. Given the open borders that exist within the EU, the wider impact of policy changes made within any one country will also deserve consideration. Section 5 of this report should serve as a useful resource for some of these discussions.

While there is much to learn from what is happening in the Americas, policy discussions should not be limited to approaches implemented there. There are several regulatory tools (e.g. minimum pricing, potency-based taxes) that receive very little attention — if any — that could have important consequences for health, public safety and/or social equity ([22]). Acknowledging that individuals (and governments) have different values and preferences for risk when it comes to cannabis policy can make for more productive discussions on this controversial topic.

([22]) Uruguay is one exception here. The government does not set a minimum price for cannabis sold in the pharmacies — it sets the price. Some provinces in Canada are contemplating THC potency taxes, while others have the authority to set a price floor.

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Appendix A: Identification and commentary on ongoing/planned studies of legalisation

Here, we identify some ongoing or planned studies from the US, Uruguay and Canada that examine the impacts of cannabis policy changes. This is not a comprehensive list; the goal is to highlight the variety of studies being conducted, to learn more about cannabis and the consequences of various policy changes.

US studies

Studies funded by the National Institutes of Health (NIH)

The NIH, largely through the National Institute on Drug Abuse (NIDA), has supported a broad portfolio of research on cannabinoids and their use in the endocannabinoid system ([23]). This includes funding ongoing research into the use of phytocannabinoids, purified cannabinoids, such as CBD and THC, and synthetic cannabinoids. In FY 2017, the NIH funded research into cannabinoids to the value of USD 140 million through various research arms, including NIDA (USD 88 million) and the National Institute on Alcohol Abuse and Alcoholism (NIAAA) (USD 21 million). In addition, the NIH provided an additional USD 36 million for research into therapeutic cannabinoids, allocating USD 16 million to NIDA and USD 6.5 million to the National Institute on Alcohol Abuse and Alcoholism (NIAAA). The NIH also provided an additional USD 15 million for research into CBD, USD 11 million of which went to NIDA.

NIDA is currently undertaking several studies that are specific to cannabis use and the impacts of legalisation. The most ambitious study is the Longitudinal Study of Adolescent Brain Cognitive Development (the ABCD study), which aims to enrol almost 12 000 healthy children aged 9 and 10 years (singletons and twins) across the US and follow them into early adulthood. According to NIDA, this is the largest long-term study of brain development and child health in the US.

The study, which is being carried out in partnership with the NIAAA, will examine how biology and environmental factors relate to developmental and physical outcomes, including mental health and life achievements. Researchers will employ brain imaging technology to evaluate changes over time. Specific to cannabis legalisation, the study will examine the impact of the changing state and local policies on youth drug use and related development. For example, it will examine the extent to which casual or regular use of cannabis during adolescence has an impact on neurodevelopment in adulthood.

The study is still currently enrolling participants. Since September 2016, researchers have enrolled just over 10 000 participants. Baseline data obtained from the first 4 500 participants, suggest that drug use among participants is minimal.

One active study by NIDA is looking at medical cannabis use among primary care patients in states with legal medical and recreational cannabis laws. The aims of the Medical Cannabis Use among Primary Care Patients study are to better understand the medical use of cannabis in a single, large health system that asks patients about their cannabis use and to describe their cannabis use behaviours and compare them with others who use cannabis without medical recommendations.

Studies funded by the National Institute of Justice (NIJ)

The NIJ is currently funding multiple studies that examine the impacts of cannabis in the US, including

([23]) See https://www.drugabuse.gov/drugs-abuse/marijuana/nih-research-marijuana-cannabinoids

one study examining the effects of Colorado's REC law on DUIs and crime ([24]). The NIJ has also funded a USD 1 million study on the impacts of marijuana legislation on law enforcement and crime in Washington state.

Studies funded by US states

Colorado ([25]) state has granted USD 9 million of public funds to cannabis research, dispersing the funds across nine studies. The studies focus on the health benefits of using medical cannabis to treat inflammatory bowel syndrome, Parkinson's disease, epilepsy (two studies), post-traumatic stress disorder (PTSD) (two studies), palliative care, insomnia and pain relief. The state has also funded USD 2.4 million of research into the public health effects of REC, focusing on driving impairment, the acute effects of dabbing ([26]), the concentration of cannabinoids in breast milk, use in older populations, the adverse effects of edibles, cardiovascular effects and a general pre/post analysis of broad public health impacts.

Under Washington ([27]) state's initiative, a portion of cannabis tax revenue is earmarked for research. For the period 2015-17, the Alcohol and Drug Abuse Institute of the University of Washington received USD 454 000 from the state's Dedicated Marijuana Fund. Current and ongoing research focuses on areas of epidemiology, chronic pain management, impacts on driving and the efficacy of innovative prevention programmes.

Uruguay

There are two ongoing academic monitoring and evaluation groups. The first is the Monitor Cannabis Uruguay group, affiliated with the School of Social Science at the University of the Republic of Uruguay. Monitor Cannabis Uruguay researches ongoing developments related to cannabis in the country. Current ongoing research focuses on the impact of the law on security. The second academic group is housed at the Catholic University of Uruguay, which maintains the Latin American Marijuana Research Initiative (LAMRI) ([28]). LAMRI is funded by the Open Society Institute (a non-governmental organisation that advocates drug policy reform) and evaluates ongoing cannabis policy trends in Uruguay and the rest of the region. LAMRI-affiliated researchers have published papers on consumption patterns, cannabis user opinions and cannabis club design in Uruguay.

The Uruguayan Drug Observatory published a preliminary study ([29]) in 2015 on drug use among university students to evaluate their opinions, prevalence and source of cannabis. Though the law had not been fully implemented, researchers included questions on home cultivation.

Canada

The Canadian government ([30]), through the Canadian Institute of Health Research, has allocated CAD 1.4 million to study the effects of cannabis legalisation on certain groups and evaluate existing regulatory models. Funds are to be distributed across 14 studies led by universities and hospitals, looking at youth prevention, exposure in pregnancy, impaired driving, trajectories of cannabis use, outcomes related to opioid use, cannabis use in the workplace, cannabis use in secondary schools, monitoring mental health outcomes and provincial responses to federal legalisation. More recently, Health Canada released tenders that focused on studies of cryptomarket cannabis sales and public attitudes.

([24]) See https://www.nij.gov/topics/drugs/Pages/research-projects.aspx
([25]) See https://www.colorado.gov/pacific/cdphe/marijuana-research
([26]) Dabbing is the action or practice of inhaling small quantities of a concentrated and vaporized drug, typically cannabis oil or resin.
([27]) See http://learnaboutmarijuanawa.org/research.htm
([28]) See https://ucu.edu.uy/es/lamri
([29]) See http://www.cicad.oas.org/oid/pubs/UniversityStudyReport_Uruguay_SPA.pdf
([30]) https://www.canada.ca/en/institutes-health-research/news/2018/01/cannabis_and_populationhealthresearch.html

Appendix B: Research papers on the impacts of recreational cannabis laws

Shading indicates presence in text.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Peer-reviewed articles							
Aydelotte et al. (2017)	Washington and Colorado 2009-15	States with similar traffic and roadways: Alabama, Indiana, Kentucky, Missouri, South Carolina, Tennessee, Texas and Wisconsin	Motor vehicle crash fatality	REC	REC adoption	Annual number of motor vehicle fatalities reported in the Fatality Analysis Reporting System; difference-in-difference approach; random effects	Pre recreational marijuana legalisation, annual changes in motor vehicle crash fatality rates for Washington and Colorado were similar to those for the control states. Post recreational marijuana legalisation, changes in motor vehicle crash fatality rates for Washington and Colorado also did not significantly differ from those for the control states (adjusted difference-in-difference coefficient = +0.2 fatalities/billion vehicle miles travelled; 95 % CI −0.4 to +0.9).
Aydelotte et al. (2019)	Washington and Colorado 2007-17	Hawaii, Montana, New Mexico, Rhode Island, Vermont, Idaho, Kansas, Nebraska, South Dakota	Monthly motor vehicle crash fatality	REC	REC implementation (i.e., when stores opened)	Annual number of motor vehicle fatalities reported in the Fatality Analysis Reporting System; difference-in-difference approach; random effects	In the five years after legalisation, fatal crash rates increased more in Colorado and Washington than would be expected had they continued to parallel crash rates in the control states (+1.2 crashes/billion vehicle miles travelled, CI: -0.6 to 2.1, $p = 0.087$), but not significantly so. The effect was more pronounced and statistically significant after the opening of commercial dispensaries (+1.8 crashes/billion vehicle miles travelled, CI: +0.4 to +3.7, $p = 0.020$).
Anderson et al. (2019)	States with MED or REC laws	States without MED or REC laws	Past-month prevalence rates	MED or REC	MED or REC adoption	Past-month prevalence rates for US high school students from the Youth Risk Behavioral Survey. Multivariate logistic regression for reporting past-month use.	MED laws not associated with any reported changes in cannabis use. REC laws were associated with an 8 % decrease (OR, 0.92; 95 % CI, 0.87-0.96).

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Bell et al. (2015)	Colorado January 2008-August 2014	Pre/post	Burns	MED REC	Pre REC to MED/REC enactment and implementation	Cross-sectional analysis of American Burn Association's National Burn Repository for hydrocarbon burns	Twenty-nine patients with butane hash oil burns were admitted to the local burn centre during the study period. No cases presented prior to medical liberalisation, 19 (61.3 %) presented during medical liberalisation (October 2009 to December 2013) and 12 presented (38.7 %) in 2014, after legalisation. The majority of patients were Caucasian (72.4 %) and male (89.7 %). The median age was 26 years (range 15-58 years). The median total body surface area covered by burns was 10 % (range 1-90 %). The median length of hospital admission was 10 days.
Bierut et al. (2017)	Washington and Colorado June-July 2015	None	Cannabis advertising online	REC	None	Cross-sectional sample of licensed retailers that advertise through Weedmaps (*n* = 146; 89 from Colorado, 57 from Washington); social media followers of Weedmaps (Twitter = 57 752; Instagram = 2 249); descriptive analysis and non-parametric hypothesis testing (chi-squared test)	Many retailers had no security measure to determine age (41 % in Colorado; 35 % in Washington). Approximately 61 % of retailers in Colorado and 44 % in Washington made health claims about the benefits of marijuana, including reduction in anxiety, depression, insomnia and pain/inflammation. Inferred demographic characteristics of followers of Weedmaps on Twitter and Instagram revealed that over 60 % were male and nearly 70 % or more were aged 20-29 years, yet some (15-18 %) were under the age of 20.
Borodovsky et al. (2017)	REC states 29 April 2016 to 18 May 2016	Non-REC states	Youth use of cannabis, including ever vaping or ever using edibles	REC, operational dispensary, home cultivation	Point in time	Cross-sectional sample of cannabis-using young people (14 to 18 years; *n* = 2 630) surveyed online; logistic and linear regression	Longer REC duration (Odds ratio (OR) vaping: 2.82, 95 % CI 2.24 to 3.55; OR edibles: 3.82, 95 % CI 2.96 to 4.94) and a higher dispensary density (OR vaping: 2.68, 95 % CI 2.12 to 3.38; OR edibles: 3.31, 95 % CI 2.56 to 4.26) were related to a higher likelihood of trying vaping and edibles. Permitting home cultivation was related to a higher likelihood (OR 1.93, 95 % CI 1.50 to 2.48) and younger age at onset (β −0.30, 95 % CI −0.45 to −0.15) of consuming edibles.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Cerdá et al. (2017)	Washington and Colorado 2010-12 and 2013-15	Non-REC states	Adolescent past-month marijuana prevalence of use and perception	REC	Pre REC to REC enactment and implementation	Repeated cross-sectional MTF surveys (*n* = 253 902); difference-in-difference approach to estimate perception/use	In Washington, perceived harmfulness declined by 14.2 % and 16.1 % among 8th and 10th graders, respectively, while marijuana use increased by 2.0 % and 4.1 % during the periods 2010-12 and 2013-15, respectively. In contrast, among states that did not legalise REC, perceived harmfulness decreased by 4.9 % and 7.2 % among 8th and 10th graders, respectively, and marijuana use decreased by 1.3 % and 0.9 % over the same periods. Difference-in-difference estimates comparing Washington with states that did not legalise REC indicated that these differences were significant for perceived harmfulness (8th graders −9.3 % (SD 3.5 %), *p* = 0.01; 10th graders −9.0 % (SD 3.8 %), *p* = 0.02) and marijuana use (8th graders: % [SD], 5.0 [1.9]; *p* = 0.03; 10th graders 3.2 % (SD 1.5 %), *p* = 0.007). No significant differences were found regarding perceived harmfulness or marijuana use among 12th graders in Washington or for any of the three grades in Colorado.
Cerdá et al. (2019)	Washington, Colorado, Oregon and Alaska 2008 to 2016	Non-REC states	Adolescent past-month marijuana prevalence of use and self-reported cannabis use disorder	REC	3-level variable determining never passed REC; before REC enactment, after REC enactment	Repeated cross-sectional NSDUH surveys; difference-in-difference approach	Among respondents aged 12 to 17 years, past-year CUD increased from 2.18 % to 2.72 % after REC enactment, a 25 % higher increase than that for the same age group in states that did not enact REC (odds ratio [OR], 1.25; 95 % CI, 1.01-1.55). Unmeasured confounders would need to be more prevalent in REC states and increase the risk of cannabis use by 1.08 to 1.11 times to explain observed results, indicating results that are sensitive to omitted variables. No associations were found among the respondents aged 18 to 25 years. Among respondents 26 years or older, past-month marijuana use after REC enactment increased from 5.65 % to 7.10 % (OR, 1.28; 95 % CI, 1.16-1.40), past-month frequent use from 2.13 % to 2.62 % (OR, 1.24; 95 % CI, 1.08-1.41), and past-year CUD from 0.90 % to 1.23 % (OR, 1.36; 95 % CI, 1.08-1.71).

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Cheng et al. (2018)	Colorado localities January 2010-August 2015		Housing values	REC		Difference-in-difference ordinary least squares estimation	Legalisation leads to an average 6 % increase in housing values, indicating that the capitalised benefits outweigh the costs. In addition, we find suggestive evidence that this relatively large housing value appreciation is probably because REC has induced strong housing demand while having no discernible effect on housing supply. Finally, authors show that the effect of REC is heterogeneous across locations and property types.
Cohn et al. (2017)	US October 2014	None	Young adult opinion for REC	Demographic	Point in time	Nationally representative cross-sectional sample of adults aged 18-34 years from the Truth Initiative Young Adult Cohort survey (n = 3 532); multinomial logistic regression	Weighted estimates showed that 39 % of the full sample and 9 % of non-marijuana users supported marijuana legalisation. Multivariable models showed that lower marijuana harm perceptions and lifetime and past 30-day tobacco use were common predictors of support for marijuana legalisation and intentions to use marijuana among non-users of marijuana. State-level marijuana policy was not associated with the level of agreement for marijuana legalisation.
Davis et al. (2016)	Colorado and Washington September 2014	None	Self-reported driving while intoxicated or within 1 hour of consuming marijuana	Demographic variables	Point in time	Online survey of past-month users (n = 865; 399 from Colorado, 446 from Washington); logistic regression	Prevalence of past-year driving while under the influence of marijuana was 43.6 % among respondents. The prevalence of driving within 1 hour of using marijuana at least five times in the past month was 23.9 %. Increased perception that driving high is unsafe was associated with lower odds of past-year marijuana DUIs (OR = 0.31, p < 0.01) and lower past-month odds of driving five or more times within 1 hour of using marijuana (OR = 0.26, p < 0.01).

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Dilley et al. (2017)	Washington June 2016	None	Local-level regulations and public opinion	REC	Point in time	Descriptive assessment of marijuana-related municipal and county ordinances (*n* = 181)	A total of 125 cities and 30 counties had passed local ordinances to address recreational marijuana retail sales. Multiple communities implemented retail market bans, including some temporary bans (moratoria), while considering whether or not to pursue other policy options. As of 30 June 2016, 30 % of the state population lived in places that had temporarily or permanently banned retail sales. Communities frequently enacted zoning policies that explicitly regulated where marijuana businesses could be established. Other policies included in ordinances placed limits on business hours and distance requirements (buffers) between marijuana businesses and youth-related land use types or other sensitive areas.
Dilley et al. (2019)	Washington 2010-12 and 2014-16	Pre/post REC	Past month prevalence			Washington Healthy Youth Survey of 8th, 10th, and 12th graders	HYS shows statistically significant declines in prevalence from 2010-2012 to 2014-2016 among both 8th graders (from 9.8 % [95 % CI, 9.1 %-10.5 %] to 7.3 % [95 % CI, 6.6 %-8.0 %]; *P* < .001) and 10th graders (from 19.8 % [95 % CI, 18.6 %-21.0 %] to 17.8 % [95 % CI, 16.7 %-18.9 %]; *P* = .01).
Estoup et al. (2016)	Washington 2010-15	Pre-REC cohort	Perceived risk and frequency of use of marijuana in adolescents	REC	No date or year specified	Self-referred students with problematic drug use, enrolled in school-base substance use intervention (*n* = 262; 144 pre-legalisation); mediation model with non-parametric hypothesis testing	Findings indicated a significantly positive correlation between marijuana-related consequences and perceived risk post legalisation. Despite relatively equal use in both groups, adolescents in the legalisation group experienced higher levels of perceived risk and increased negative consequences.
Everson et al. (2019)	Washington 2009-16	None. Proximity to dispensary	Past month prevalence	REC	REC enactment and proximity to nearest retail outlet to respondent ZIP code	Washington Behavioral Risk Factor Surveillance System (BRFSS)	Current use increased among adults living in areas within 18 miles of a retailer and, especially, within 0.8 miles (odds ratio [OR] = 1.45; 95 % confidence interval [CI] = 1.24, 1.69). Frequent use increased among adults living within 0.8 miles of a retailer (OR = 1.43; 95 % CI = 1.15, 1.77).

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Fiala et al. (2017)	Oregon November 2015 and April-May 2016	Pre/post	Viewing marijuana promotion	Demographic variable and county of residence	None	Repeated cross-sectional online survey (n = 4 001) of adults (18+ years); non-parametric hypothesis testing (chi-squared test).	More than half of adults (54.8 %) state-wide reported seeing marijuana advertising in the past month. These adults reported that they most frequently saw store-front (74.5 %), street-side (66.5 %) and billboard (55.8 %) advertising. Exposure did not significantly differ by participant's age or marijuana use but was higher among those living in counties with retail sales (56.5 %) than among those living in counties without (32.5 %).
Freisthler et al. (2017)	Denver census tracts January 2013-October 2015	None	Violent, property and marijuana-specific crime (crimes that involved marijuana and licensed facilities)	REC	MED/REC dispensary density over time	Denver Police data of 481 census blocs over 34 months (n = 16 354); Bayesian Poisson space-time model	Independent of the effects of covariates, densities of marijuana outlets were unrelated to property and violent crimes in local areas. However, the density of marijuana outlets in spatially adjacent areas was positively related to property crime in spatially adjacent areas over time. Furthermore, the density of marijuana outlets in local and spatially adjacent block groups was related to higher rates of marijuana-specific crime. This study suggests that the effects of the availability of marijuana outlets on crime do not necessarily materialise within the specific areas where these outlets are located but may materialise in adjacent areas.
Grant et al. (2017)	Washington February 2001 to July 2015	Pre-REC cohort	Self-reported past-month use of marijuana in pregnant women	REC	Pre REC to REC enactment and implementation	Women enrolled in the Parent-Child Assistance Program (n = 1 359; pre REC = 997, post REC = 362); non-parametric hypothesis testing (chi-squared test)	Women who completed the intervention after marijuana legalisation were significantly more likely (OR = 2.1, $p < 0.0001$) to report marijuana use on exiting the programme than women who completed the intervention before marijuana legalisation. Across both cohorts (pre and post legalisation), the authors found a positive link between marijuana use on exit and alcohol, illegal methadone, other opioids, amphetamines and cocaine use.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Hall, K. E. et al. (2018)	Colorado 2012-14	Pre/post	ED episodes	REC	Pre-REC to REC implementation	Colorado Hospital Association data	State-wide data demonstrated a fivefold rise in the prevalence of mental health diagnoses among cannabis-associated ED visits (prevalence rate = 5.35, 95 % CI 5.27 to 5.43), compared with ED visits not related to cannabis. The hospital subpopulation supported this finding with a fourfold rise in the prevalence of psychiatric complaints among ED visits attributable to cannabis (prevalence rate = 4.87, 95 % CI 4.36 to 5.44), compared with ED visits that were not attributable to cannabis. State-wide rates of ED visits associated with both cannabis and mental health significantly increased from 224.5 per 100 000 in 2012 to 268.4 per 100 000 in 2014 ($p < 0.0001$).
Hunt and Pacula (2017)	Colorado and Washington October 2013, May 2014, October 2014	Pre-REC cohort	Reported retail price	REC/MED	REC enactment to REC implementation	Longitudinal survey of three waves (RAND Marijuana Use in West Coast States Survey) (n = 317 past-month users); Weedmap data on price (n = 3 802); difference-in-difference approach	Results indicate that there were no impacts on the prices paid for medical or recreational marijuana by state representative residents within the short 4- to 5-month window following legalisation. However, there were differences in how much people paid for marijuana for recreational purposes from a recreational store.
Jones et al. (2018)	Colorado October 2013 to March 2015	US (whether REC was in place or not)	Frequency of marijuana use in college students	REC	REC enactment to REC implementation	Repeated cross-sectional surveys (n = 1 413; pre REC = 424; post REC = 989), compared with responses from National College Health Assessment for 2015; parametric hypothesis testing, ANOVA	The prevalence of marijuana use in Colorado college students is much higher than the national average (71 % v 39 %, respectively; $p < 0.001$), especially the percentage of daily or almost daily users (25 % v 2 %, respectively; $p < 0.001$). There were significant differences found between non-users of marijuana and the marijuana users that use once a week or more but not daily in regard to the grade point average ($F_{(6,227)} = 2.935$, $p < 0.001$). In addition, it seems that the relationship between alcohol and marijuana use in general has decreased since Amendment 64 was passed but not among binge drinkers.
Kerr, D. et al. (2017)	Students in one large public university in Oregon 2012-16	Students from six universities in non-REC states	Changes in marijuana, alcohol and cigarette use in college students	REC	Pre REC to REC enactment and implementation in July 2015	Repeated cross-sectional survey (n = 10 924) of undergraduates; mixed-effects logistic regression	Rates of Oregon college students' marijuana use increased (relative to that of students in other states) following recreational marijuana legislation in 2015 but only for those who reported recent heavy use of alcohol.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Kerr, D. et al. (2018)	University students in Oregon 2008-16	Students from 123 other universities in non-REC states	Changes in cannabis use prevalence	REC	REC implementation	Repeated cross-sectional survey in Oregon (*n* = 7 412) and 123 institutions (*n* = 274 340)	Following REC, Oregon students (compared to non-REC-state students) showed relative increases in rates of marijuana use (odds ratio [OR] = 1.29, 95 % confidence interval [CI: 1.13, 1.48], *p* = .0002, and decreases in tobacco use rates (OR = .71, 95 % CI [.60, .85], *p* < .0001).
Kerr, W. C. et al. (2018)	Washington 2012, 2014-15	None	Self-reported past-year use in survey year and in 2012 in adults	REC	Pre REC to REC enactment and implementation	Cross-sectional representative phone surveys (*n* = 3 451); multinomial logistic regression	A small increase of 1.2 percentage points in past-year use prevalence, from 24.3 % (22.3-26.5 %) to 25.6 % (23.6-27.6 %), which is not statistically significant, was found when combining the surveys. No statistically significant change was found in the prevalence of the simultaneous use of cannabis and alcohol — it decreased from 12.9 % (11.3-14.7 %) to 12.6 % (11.0-14.4 %).
Kerr, W. C. et al. (2017)	Respondents in states with REC/MED policy 1984-2015	Respondents in states without REC/MED policy	Past-year marijuana use	MED, REC, provision for dispensary, home cultivation	REC adoption	Repeated cross-sectional quinquennial National Alcohol Survey of adults (18+) (*n* = 37 359); fixed-effects approach for age-period-cohort effects	Period effects were the main driver of rising marijuana use prevalence. Models including indicators of medical and recreational marijuana policies did not find any significant positive impacts.
Kim and Monte (2016)	Colorado 2001-14	Pre/post	ED episodes for cannabis	MED REC	Pre REC to MED/REC enactment and implementation	Retrospective data from the Colorado Hospital Association, a consortium of more than 100 hospitals in the state; parametric hypothesis testing	The prevalence of hospitalisations for marijuana exposure in patients aged 9 years and more than doubled after the legalisation of medical marijuana (from 15 per 100 000 hospitalisations during the period 2001-09 to 28 per 100 000 hospitalisations during the period 2010-13; *p* < 0.001), and ED visits nearly doubled after the legalisation of recreational marijuana (from 22 per 100 000 ED visits during the period 2010-13 to 38 per 100 000 ED visits during January to June 2014; *p* < 0.001).

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Kim et al. (2016)	Colorado 2011-14	Pre/post	ED episodes for cannabis	REC	Pre REC to MED/REC enactment and implementation	Retrospective data from Colorado Hospital Association	The data from the Colorado Hospital Association did not show a significant change from 2011 to 2012 in the rate of ED visits with ICD-9 codes of cannabis use among out-of-state residents; however, from 2012 to 2014, the state-wide rate among out-of-state residents rose from 78 per 10 000 visits in 2012 to 112 per 10 000 visits in 2013 and 163 per 10 000 visits in 2014 (rate ratios, 1.44 (2012-13) and 1.46 (2013-14); $p < 0.001$ for both comparisons). Among Colorado residents, from 2011 to 2014, the rate of ED visits possibly related to cannabis use increased from 61 to 70, 86 and 101, respectively, per 10 000 visits (rate ratios, 1.14 (2011-12), 1.24 (2012-13) and 1.17 (2013-14); $p < 0.001$ for all comparisons).
Lane and Hall (2019)	Colorado, Washington and Oregon 2009-16	Kansas, Nebraska, New Mexico, Oklahoma and Utah (Colorado neighbours); British Columbia and Oregon (Washington neighbours); and California and Nevada (Oregon neighbours)	Monthly motor vehicle fatalities	REC	REC implementation in each state	Interrupted time series using CDC WONDER data on vehicle fatalities	There was a pooled step increase of 1.08 traffic fatalities per million residents followed by a trend reduction of −0.06 per month (both $P < 0.001$). The results suggest that legalizing the sale of cannabis for recreational use can lead to a temporary increase in traffic fatalities in legalizing states that can spill over into neighbouring jurisdictions.
Livingston et al. (2017)	Colorado 2000-15	Pre/post	Monthly opioid-related fatalities	REC	REC implementation January 2014	Interrupted time series	Colorado's legalisation of recreational cannabis sales and use resulted in a 0.7 deaths-per-month ($b = −0.68$; 95 % CI = −1.34 to −0.03) reduction in opioid-related deaths. This reduction represents a reversal of the upwards trend in opioid-related deaths in Colorado.
Makin et al. (2018)	Colorado and Washington 2010-15	The rest of the US as one unit	Violent and property crime clearance rates	REC	Pre REC to REC enactment	Monthly counts of crime from FBI Uniform Crime Reporting data; interrupted time-series analysis	Findings suggest there are no negative effects of legalisation on crime clearance rates. Moreover, evidence suggests that some crime clearance rates have improved. Our findings suggest legalisation has resulted in improvements in some clearance rates.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Mason et al. (2016)	Washington 2010/11 to 2013/14	Pre-REC cohort	Self-reported past-month use in adolescents	Second survey wave (just prior to REC)	Pre REC to REC enactment	Two wave cohort study of 8th/9th graders from Tacoma, Washington (n = 238); multivariate, multilevel modelling	Marijuana use was higher for the second cohort than for the first cohort, but this difference was not statistically significant. Rates of cigarette and alcohol use were slightly lower in the second cohort than in the first cohort.
McGinty et al. (2017)	Respondents in states that passed REC April 2016	Respondents in states that did not pass REC	Public opinion and arguments for/against legalisation	REC	Point in time	Nationally representative sample of US adults (n = 979; 334 from Colorado, Washington, Arkansas, Oregon, DC); ordered logit and non-parametric hypothesis testing (chi square)	Respondents rated pro-legalisation arguments highlighting beneficial economic and criminal justice consequences as more persuasive than anti-legalisation arguments, emphasising adverse public health effects. Respondents were more likely to agree with arguments highlighting legalisation's potential to increase tax revenue (63.9 %) and reduce prison overcrowding (62.8 %) than arguments emphasising the negative consequences of motor vehicle crashes (51.8 %) and youth health (49.6 %). The highest rated anti-legalisation arguments highlighted the conflict between state and federal marijuana laws (63.0 %) and asserted that legalisation will fail to eliminate the illicit market (57.2 %). Respondents who endorsed pro-legalisation economic and criminal justice arguments were more likely than other respondents to support legalisation. Respondents living in Arkansas, Colorado, DC, Oregon and Washington were significantly ($p < 0.05$) more likely to agree with 11 of the 13 pro-legalisation arguments and significantly less likely to agree with 10 of the 13 anti-legalisation arguments than respondents living in non-legalisation states.
Miller et al. (2017)	Washington 2005-15	Pre-REC cohort	Past-month marijuana use in college students	REC	Pre REC to REC enactment and implementation	Repeated cross-sectional surveys of undergraduates at Washington State University who participated in the National College Health Assessment (n = 13 335); logit and OLS regression	Students at Washington State University experienced a significant increase in marijuana use after legalisation. This increase is larger than the increase that would be predicted by national trends. The change is strongest among females, Black students and Hispanic students. The increase for underage students is as much as that for legal-age students. We find no corresponding changes in the consumption of tobacco, alcohol or other drugs.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Pacula et al. (2016)	Colorado and Washington October 2013	Oregon and New Mexico	Prevalence rates and use behaviours between MED and REC users	REC	Point-in-time measure during REC enactment	Cross-sectional sample of representative phone survey (*n* = 1 994; Washington = 787, Oregon = 506; Colorado = 503; New Mexico = 213)	Recreational use is considerably higher than medical use across all states (41 %), but it is the highest in Oregon and Washington. Approximately 86 % of people who report ever using cannabis for medicinal purposes also use it recreationally. Fewer than one in five recreational users report simultaneous use of alcohol and cannabis most or all of the time, and fewer than 3 % of medicinal users report frequent simultaneous use of alcohol and cannabis. In the US, the degree of overlap between medicinal and recreational cannabis users is 86 %. Medicinal and recreational cannabis users favour different modes and amounts of consumption.
Parnes et al. (2018)	Colorado Spring 2013 to autumn 2015	Pre-REC cohort	Self-reported cannabis use in college students	REC	REC enactment to implementation	Undergraduate survey (*n* = 5 241); non-parametric hypothesis test (chi-squared test)	Cannabis use has increased for all students since recreational legalisation, but more so for those over 21 years. No differences in past-month use frequency were found between pre- and post-legalisation. The influence of cannabis laws on non-resident students' decision to attend a Colorado college predicted lifetime and past 30-day use. In addition, out-of-state students reported higher past 30-day use than in-state students.
Rusby et al. (2018)	Oregon Spring 2014 and 2015	Pre-REC cohort	Self-reported cannabis use in adolescents	REC	REC enactment to implementation	Two cohorts of 8th/9th graders (*n* = 444); multivariate linear regression	In communities opting out of sales, the prior-to-legalisation cohort was less likely to increase their willingness and intent to use marijuana, and the legalisation cohort was more likely to increase their intent to use. For young people who used marijuana, legalisation was associated with increased use, and those in communities opting out of sales experienced a larger growth in marijuana use. Community policy appears to impact young people's attitudes towards and use of marijuana. The results suggest that the legalisation of recreational marijuana did not increase marijuana use among young people who did not use marijuana, but it did increase use among young people who were already using.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Smart et al. (2017)	Washington July 2014-September 2016	None	Changes in price, potency and product	REC	Post REC implementation only	Transaction sale data from regulators	Traditional cannabis flowers still account for the majority of spending (66.6 %), but the market share of extracts for inhalation increased by 145.8 % between October 2014 and September 2016, now comprising 21.2 % of sales. The average THC-level for cannabis extracts is more than triple that for cannabis flowers (68.7 % compared to 20.6 %). For flower products, there is a statistically significant relationship between price per gram and both THC [coefficient = 0.012; 95 % confidence interval (CI) = 0.011–0.013] and CBD (coefficient = 0.017; CI = 0.015–0.019). The estimated discount elasticity is +0.06 (CI = +0.07 to +0.05). Traditional cannabis flowers still account for the majority of spending (66.6 %), but the market share of extracts for inhalation increased by 145.8 % between October 2014 and September 2016, now accounting for 21.2 % of sales. The average THC level for cannabis extracts is more than triple that for cannabis flowers (68.7 % compared with 20.6 %). For flower products, there is a statistically significant relationship between price per gram and both THC (coefficient = 0.012; 95 % CI 0.011 to 0.013) and CBD (coefficient = 0.017; 95 % CI 0.015 to 0.019). The estimated discount elasticity is –0.06 (95 % CI –0.07 to –0.05).
Subbaraman and Kerr (2016)	Washington January-October 2014	Pre/post	Support for legalisation	Demographic variable	Post REC implementation	Random digit dialling of residents (*n* = 2007); bivariate tests and multivariate regressions	Less than 5 % of those who voted for marijuana legalisation would change their vote, whereas 14 % of those who voted against legalisation would change their vote. In multivariable models controlling for demographics, substance use and marijuana-related opinions, those who voted for legalisation had half the odds of changing their vote than those who voted against it. Among past-year non-marijuana users, almost 10 % were somewhat/very likely to use marijuana if they could buy it from a legal store.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Sokoya et al. (2018)	Denver, Colorado 2012-15	Pre/post	ED visits	REC	Pre REC to MED/REC enactment and implementation	Hospital data from the University of Colorado Hospital and Denver Health Medical Centre; non-parametric hypothesis test	Maxillary and skull base fracture proportions significantly increased following legalisation ($p < 0.001$ and $p < 0.001$, respectively). No significant differences were seen in the proportion of patients who lived in urban and rural counties before and after legalisation ($p > 0.05$).
Wang et al. (2016)	Colorado 2009-15	Pre/post	Paediatric exposures to marijuana	MED REC	Pre REC to MED/REC enactment and implementation	Retrospective cohort study of hospital child admissions at Children's Hospital Colorado and cannabis exposure incidents reported to poison control; Poisson regression	The mean rate of marijuana-related visits to the children's hospital increased from 1.2 per 100 000 population 2 years prior to legalisation to 2.3 per 100 000 population 2 years after legalisation ($p = 0.02$). Annual poison control paediatric marijuana cases increased more than fivefold from 2009 (9) to 2015 (47). Colorado had an average increase in poison control cases of 34 % ($p < 0.001$) per year, while the remainder of the US had an increase of 19 % $p < 0.001$).
Wang et al. (2017)	Colorado 2000-15	Pre/post	Annual rates of hospitalisations, ED events and poison control calls for marijuana	MED REC	Pre REC to MED/REC enactment and implementation	Univariate Poisson regression	From 2000 to 2015, hospitalisation rates with marijuana-related billing codes increased from 274 per 100 000 hospitalisations to 593. Overall, the prevalence of mental illness among ED visits with marijuana-related codes was five times higher (5.07, 95 % CI 5.0 to 5.1) than the prevalence of mental illness among ED visits without marijuana-related codes. Poison control calls remained constant from 2000 to 2009. However, in 2010, after local medical marijuana policy liberalisation, the number of marijuana exposure calls significantly increased, from 42 to 93; in 2014, after recreational legalisation, calls significantly increased by 79.7 %, from 123 to 221 ($p < 0.0001$).
Wang et al. (2018)	Colorado 2005-15	Pre/post	Children ED visits for cannabis	REC MED	Pre REC to MED/REC enactment and implementation	Retrospective review of annual number of marijuana-related visits to ED ($n = 4\ 202$)	Marijuana-related visits increased from 1.8 per 1 000 visits in 2009 to 4.9 in 2015 ($p = < 0.0001$).

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Wen and Hockenberry (2018)	Alaska, Colorado, Oregon and Washington Q1 2011 to Q2 2016	Non-REC states	State-level opioid prescribing rates covered by Medicaid	MED REC	REC implementation	State drug utilisation data from the Centres for Medicare and Medicaid Services; difference-in-difference approach, two-way fixed effects	The state implementation of medical marijuana laws was associated with a 5.88 % lower rate of opioid prescribing (95 % CI −11.55 % to approximately −0.21 %). Moreover, the implementation of adult-use marijuana laws, which all occurred in states with existing medical marijuana laws, was associated with a 6.38 % lower rate of opioid prescribing (95 % CI −12.20 % to approximately −0.56 %).
Shi et al. (2016)	Census tracts in Colorado 2015		REC and MED store density	MED REC		Cross-sectional ecological study of all census tracts in the state (n = 1 249); parametric hypothesis testing	Regardless of store type, marijuana stores were more likely to be located in neighbourhoods that had a lower proportion of young people, a larger racial and ethnic minority population, a lower household income, a higher crime rate or a greater density of on-premise alcohol outlets. The availability of medical and recreational marijuana stores was differentially correlated with household income and racial and ethnic composition.
Working papers							
Hansen et al. (2017b)	Washington 2015	Pre/post	Inter-state trafficking after REC implementation in Oregon	REC (opening of retail stores in Oregon)	REC implementation in Oregon	Washington retail transaction data; regression discontinuity design	Washington retailers situated along the Oregon border experienced a 41 % decline in sales immediately following Oregon's cannabis market opening. In counties that are the closest crossing point for the majority of the neighbouring population, the estimated decline in sales has grown to 58 % and is the largest for the biggest transactions.

Reference	Location and years evaluated	Control measures	Outcome	Independent variable(s)	REC-specific policy change	Data and methods	Findings
Hansen et al. (2018)	Washington and Colorado 2000-16	Non-REC states in the US	Motor vehicle crash fatality	REC	REC implementation in 2014	Annual number of motor vehicle fatalities reported in the Fatality Analysis Reporting System; synthetic control approach	Between 2013 and 2016, the number of drivers who tested positive for THC increased in Colorado and Washington, by 92 % and 28 % respectively. However, identifying a causal effect is difficult because of the presence of significant confounding factors. Hansen et al. found that 'the synthetic control groups saw similar changes in marijuana-related, alcohol-related and overall traffic fatality rates despite not legalising recreational marijuana'.
Hao and Cowan (2017)	Counties in Washington and Colorado 2009-14	Counties in neighbouring states just over the border	Arrests and self-reported marijuana use	REC	Pre REC to REC enactment	FBI Uniform Crime Reporting Data at county level; NSDUH state-level prevalence data; difference-in-difference approach, synthetic controls for robustness check	There is no conclusive evidence that marijuana sale/manufacture arrests, DUI arrests or opium/cocaine possession arrests in border states are affected by REC. The NSDUH data show that self-reported marijuana use in states that border REC states increased after REC, compared with those states that do not share borders with REC states.
Highway Loss Data Institute (2017)	Colorado, Washington and Oregon January 2012 to October 2016	Neighbouring states: Nebraska, Utah, Wyoming, Montana, Idaho and Nevada	Auto insurance collision claim rates	REC	REC implementation	Monthly insurance collision claims; Poisson regression and non-parametric hypothesis testing	Results from single-state analyses as well as the combination of the three states indicate that collision claim frequencies increased significantly when retail sales commenced. When states are examined individually, the frequency of collision claims increases by between 4.5 % and 13.9 %. A single analysis that combined the three states with legal recreational use found a smaller yet significant increase of 2.7 %.

REC, recreational marijuana law; MED, medical marijuana law; SD, standard deviation; ANOVA, analysis of variance; OLS, ordinary least squares.

REC adoption: when an initiative was passed by voters but was not in effect.

REC enactment: when laws were put into place to effect a legal change.

REC implementation: when the laws were fully operational and stores were open. Note: advocate-produced reports are not included.

Appendix C: Additional trend data

Prevalence

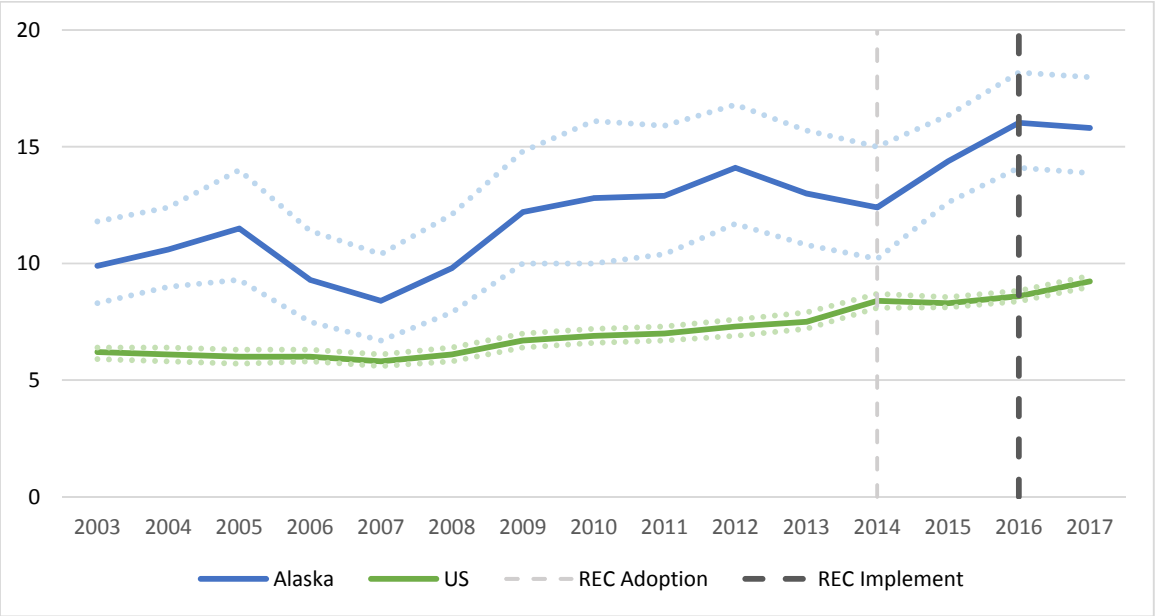
In the figures below, we plot prevalence rates reported by the NSDUH for various age cohorts and states. To help the reader, we also include a reference table of legal MED/REC dates of adoption and implementation, the latter referring to when qualified patients or adults were able to access and use cannabis. Keep in mind that many early MED states did not have any dispensaries or commercial store fronts for several years after adopting or implementing MED.

TABLE AC1
Dates of MED/REC adoption and implementation

	Medical cannabis		Recreational cannabis	
State	**Adoption**	**Year that stores legally opened**	**Adoption**	**Implementation**
Alaska	November 1998	NA	November 2014	October 2016
Colorado	November 2000	2005	November 2012	January 2014
District of Columbia	November 1998	2010	November 2014	February 2015
Oregon	November 1998	2009	November 2014	October 2015
Washington	November 1998	NA	November 2012	July 2014

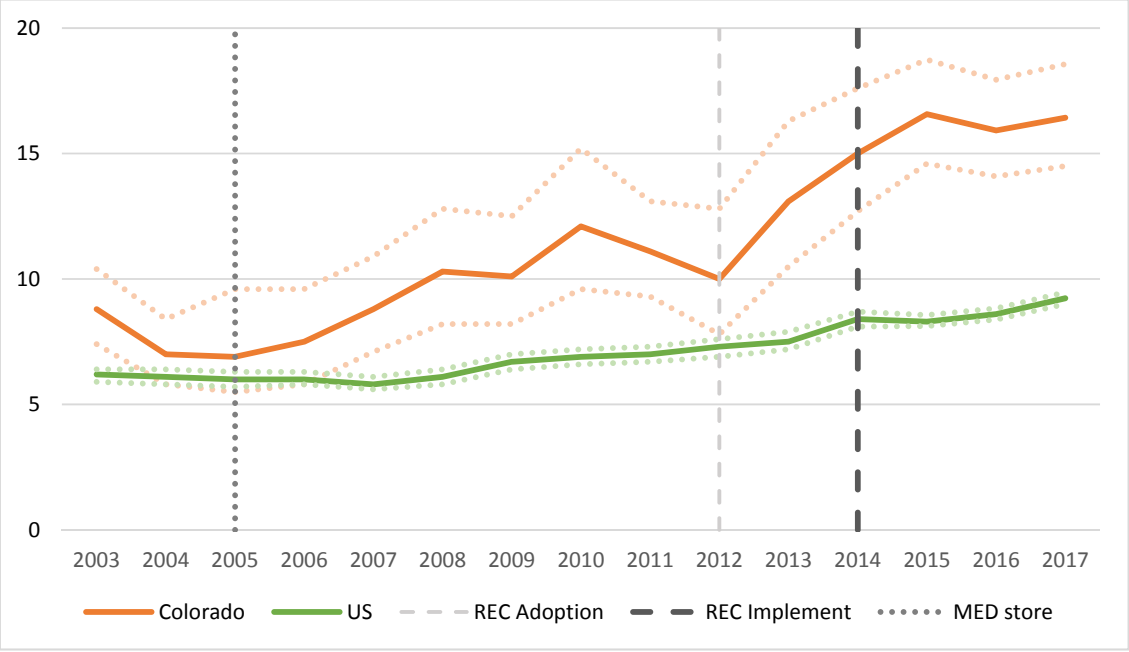
The series of charts below plot the past-month prevalence rate of use of cannabis among the general population (aged 12 and over) in Alaska, Colorado, DC, Oregon, Washington and the US as a whole between 2003 and 2017. State estimates were taken from the NSDUH's 2-year pooled estimates, assigning the latter year for each of the year (e.g. pooled estimates for 2016 to 2017 represent 2017). To show the change in prevalence rates relative to policy changes, we have plotted vertical dashed/dotted lines to indicate the year in which MED dispensaries opened (a dotted line, where applicable), when REC was adopted (i.e. voted into law; this is represented by a light-grey dashed line) and when REC was implemented (i.e. when stores started opening; this is represented by a dark-grey dashed line). Because we are using annual data, these vertical lines roughly approximate the timing of a policy change. For example, voters of a state may have adopted REC in November 2014, even though the year was nearly over after the law passed.

FIGURE AC1
Past-month cannabis use prevalence (%) in Alaska among those aged 12 years and older



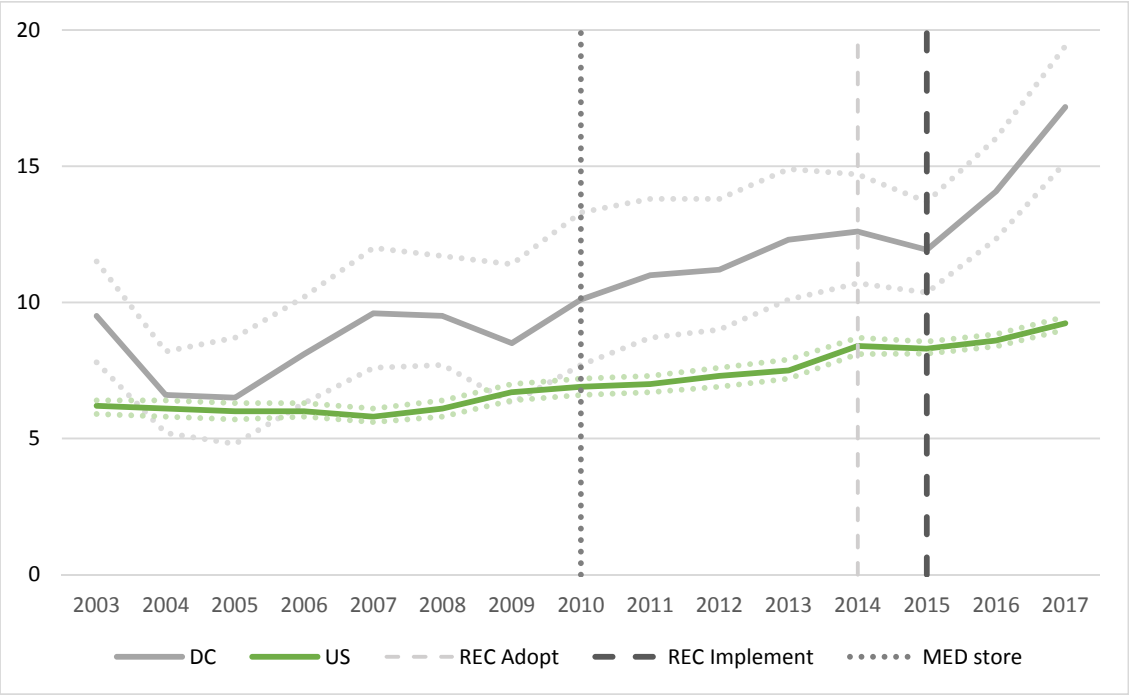
Source: NSDUH

FIGURE AC2
Past-month cannabis use prevalence (%) in Colorado among those aged 12 years and older



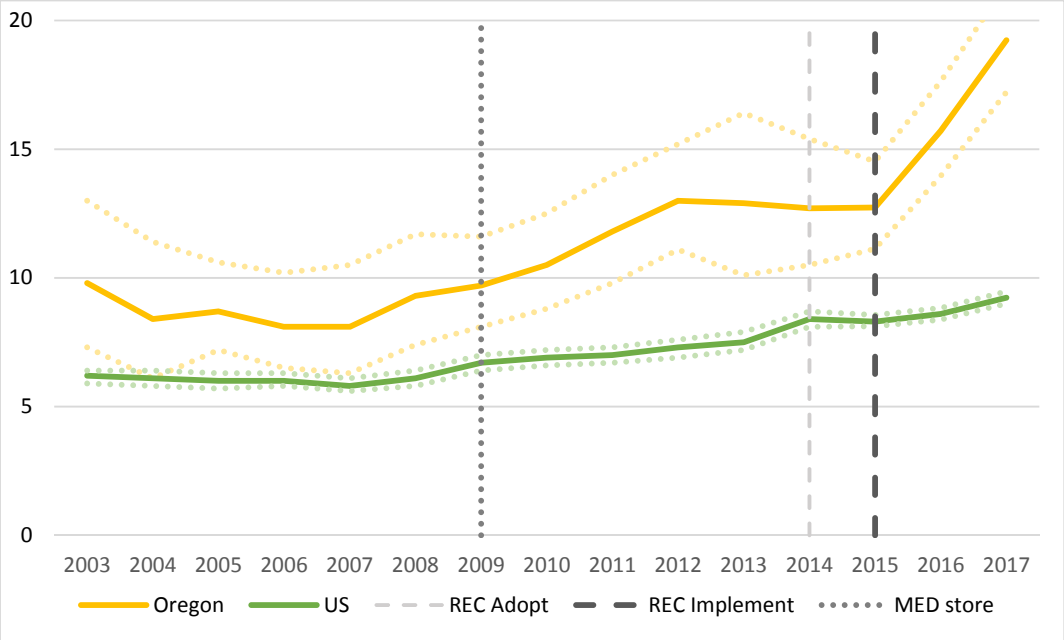
Source: NSDUH

FIGURE AC3
Past-month cannabis use prevalence (%) in DC among those aged 12 years and older



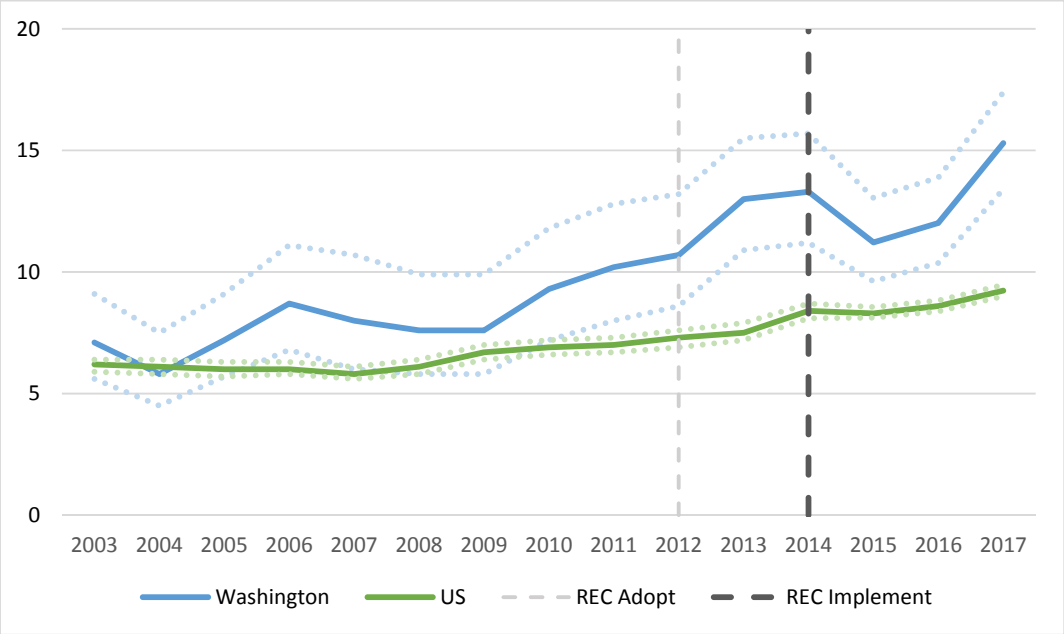
Source: NSDUH

FIGURE AC4
Past-month cannabis use prevalence (%) in Oregon among those aged 12 years and older



Source: NSDUH

FIGURE AC5
Past-month cannabis use prevalence (%) in Washington state among those aged 12 years and older



Source: NSDUH

Data from the MTF survey show little change in past-month cannabis use among 8th, 10th and 12th graders (pooled) between 2009 and 2017. In 2009, 13.8 % of respondents reported using cannabis at least once in the past month. This rate peaked in 2013, at 15.6 %, declining to 14.5 % in 2017. However, past-month use rates have steadily increased among college students. In 2009, 18.5 % of respondents reported using cannabis at least once in the past month. By 2016, the rate had climbed to 22.2 %.

Data from biennial state surveys add additional information to the changes in prevalence rates among high school students post REC. These state surveys randomly sample students from selected middle schools and high schools. The HKCS sampled about 17 000 students from 157 schools across the state in 2015. The Washington state's HYS surveyed over 230 000 students in over 1 000 schools in 2016. In Table AC2 we report available prevalence estimates for high school students and adults reported in state surveys in recent years, along with estimates from the Behaviour Risk Factor Surveillance System (BRFSS) of the Centers for Disease Control and Prevention. However, past-month prevalence rates among high school students or 12th graders have remained flat or declined in both states.

TABLE AC2
Surveys and reported past-month cannabis prevalence rates for Colorado and Washington

Survey	2009/10	2011/12	2013/14	2015/16
Colorado, past-month (18+) BRFSS			13.6	13.5
Colorado, daily/near-daily (18+) BRFSS			6	6.35
Colorado, past-month (high school) HKCS*	25	22	20	21
Washington, past-month (12th grade) HYS	26	27	27	26
Washington, heavy past-month (12th grade) HYS**		9	10	11

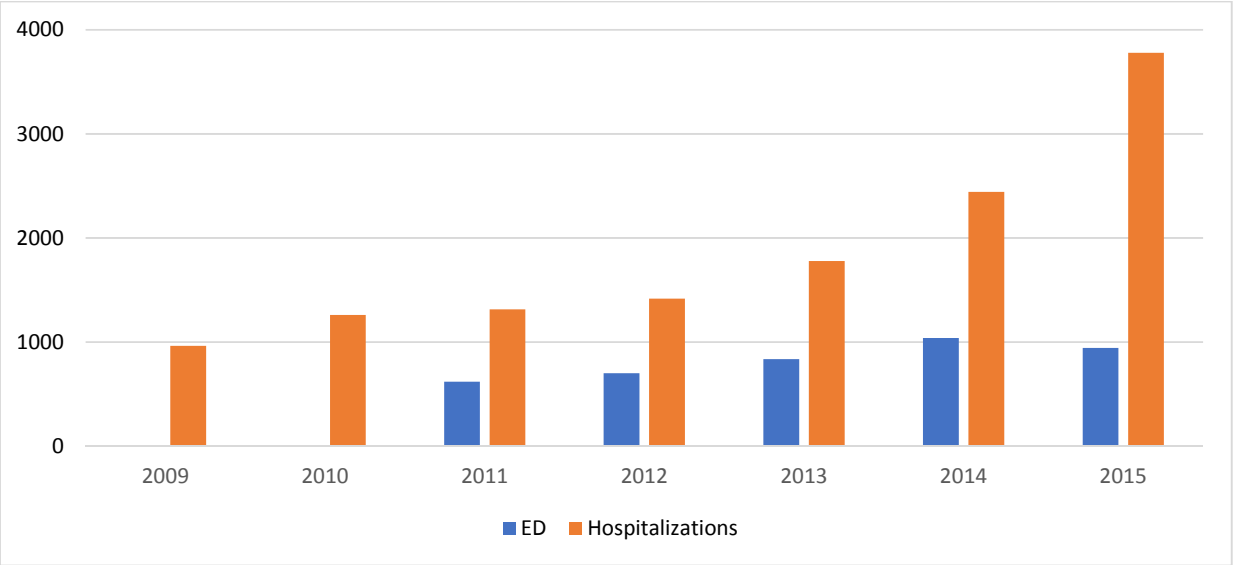
*Estimates are for odd years; otherwise they are even.

**Heavy use is defined as using on 10+ days in the last 30.

Hospital and poison control centres

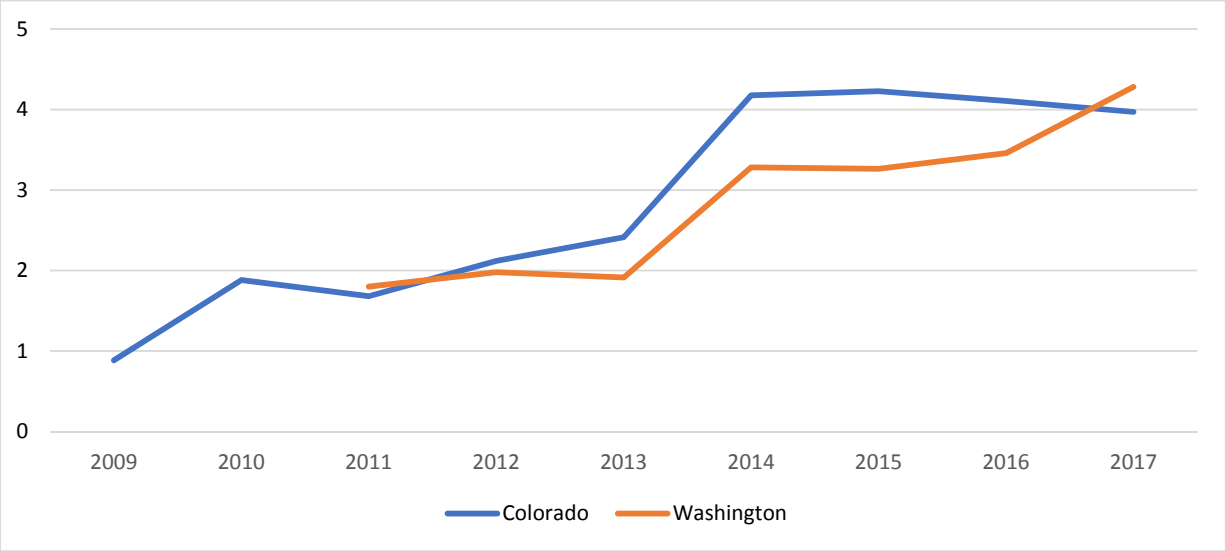
Data from hospitals and poison control centres allow researchers to gauge the initial public health incidents associated with post-REC implementation. Below we plot the rate of ED events and hospitalisations involving cannabis. ED episodes have increased since 2011 but not as rapidly as hospitalisations. Rates remained relatively flat until 2013, when they started to rise just prior to REC enactment. Data for 2015 are an estimated annual rate, as only counts from January to September are publicly available. We were unable to find ED or hospitalisation data from Washington state.

FIGURE AC6
Adverse events involving cannabis per 100 000 population in Colorado



The figure below shows the reported calls to poison control centres involving cannabis per 100 000 residents for both Washington and Colorado. In Colorado since 2011, calls involving cannabis between 2011 and 2014, when they levelled off in 2014 at about 4 per 100 000. Washington saw a similar increase, with rates rising in 2014, then levelling off for 2 years before rising again in 2016/17 to similar per capita rates as in Colorado.

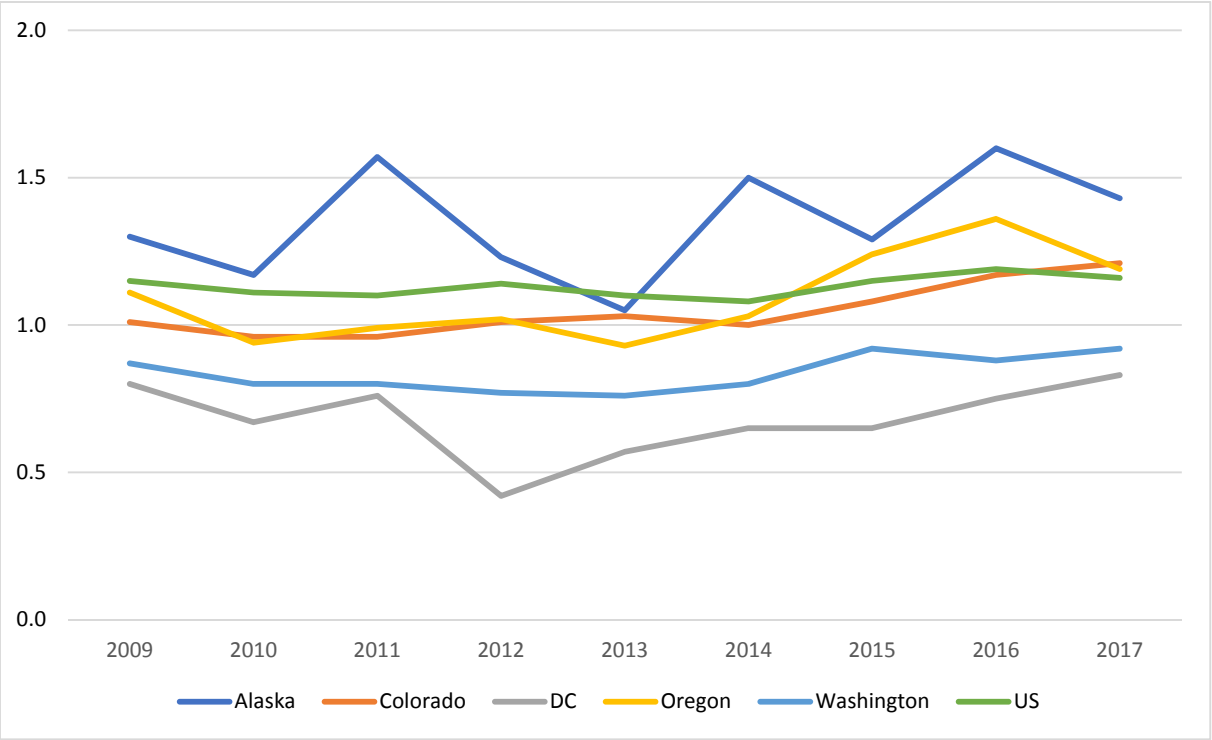
FIGURE AC7
Poison control calls per 100 000 population



Traffic fatalities

The National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS) reports data on the number of traffic fatalities per 100 million vehicle miles travelled. The rate of traffic fatalities in most states analysed was fairly linear between 2009 and 2017 (the obvious exceptions are DC, which is mostly urban, and Alaska, which is mostly rural; both may suffer from extreme year-to-year variability). However, starting around 2013, Oregon, Colorado and Washington show a marked increase compared with the rest of the US.

FIGURE AC8
Traffic fatality rate per 100 million vehicle miles travelled



Source: FARS

Arrests for cannabis possession and supply offences

The figures below show rates of arrest for cannabis offences over time (where available). In all three states, arrest rates for cannabis offences have declined over the period.

FIGURE AC9
Cannabis possession arrests per 100 000 population

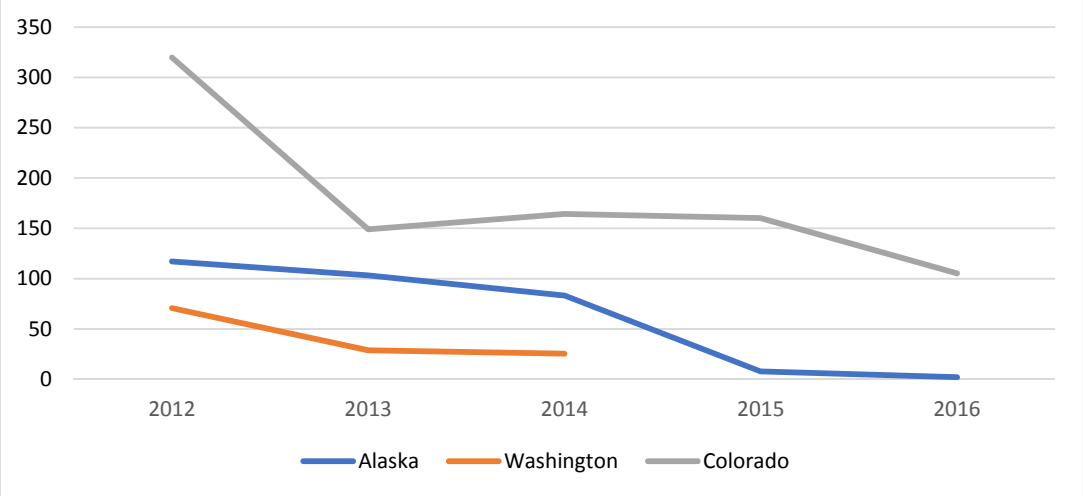


FIGURE AC10
Cannabis supply arrests per 100 000 population