Emissions Trading in Mexico: Analysis of Carbon Leakage Risks

SEMARNAT
SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

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Abbreviations

AF: Assistance Factor

BAU: Business as Usual

BCA: Border Carbon Adjustments

BOF: Basic Oxygen Furnace

CDM: Clean Development Mechanism

CGE: Computable General Equilibrium

CHP: Combined Heat and Power

EAF: Electric Arc Furnace

EITE: Emission-Intensive and Trade-Exposed

ETS: Emissions Trading Scheme

EU ETS: European Union Emissions Trading Scheme

FSB: Fixed-Sector Benchmarking

GHG: Greenhouse Gas

GVA: Gross Value Added

GViEW: Global Vivid Economy-Wide

LGCC: General Law on Climate Change

NDC: Nationally Determined Contribution

RENE: National Emissions Registry

OECD: Organisation for Economic Co-operation and Development

OBA: Output-Based Allocation

ROW: Rest of the World

RGGI: Regional Greenhouse Gas Initiative

SRF: Solid Recovered Fuel

WTO: World Trade Organisation

Executive summary

Under the Paris Agreement, Mexico has submitted ambitious greenhouse gas (GHG) reduction targets. In its Nationally Determined Contribution (NDC), Mexico announced its intention to reduce emissions by 22% relative to BAU. This is an economy-wide target covering all GHGs and is estimated to be equivalent to a reduction of 210 MtCO_2e by 2030. The NDC identifies activities will need to be undertaken across a wide range of sectors including the industrial sector.

Mexico intends to achieve its emissions reduction partly through an Emissions Trading Scheme (ETS), which might adversely impact the relative international competitiveness of Mexico's emission-intensive and trade-exposed (EITE) sectors. In a world of asymmetric carbon policies, the introduction of carbon pricing in Mexico will increase the production costs for many sectors relative to international peers who have not introduced carbon pricing, at least in the short term.

This could result in carbon leakage, which occurs when economic activity is shifted to another jurisdiction as a result of asymmetric carbon pricing between the two jurisdictions. Carbon pricing could increase Mexican firms' production costs, at least in the short term. If the cost increase is substantial and international competition is strong, this could lead to a loss of production in firms in jurisdictions without, or with less stringent, carbon pricing policies. Some or all of the emission reductions achieved domestically could be offset by higher emissions elsewhere – this is carbon leakage.

There are three key channels through which carbon leakage may occur:

1. The output or short-term competitiveness channel operates through distorted output decisions: higher carbon emission costs can cause firms affected by carbon pricing to lose market share to the benefit of those not covered by carbon pricing.
2. The investment or long-term competitiveness channel: different carbon prices alter firm investment decisions between countries. In the medium-term this can occur through reduced investment in maintenance capital; in the longer-run, existing plants in jurisdictions with more stringent carbon regulation may close and/or new plants may be preferentially located in jurisdictions without carbon pricing (or with less stringent pricing).
3. The fossil fuel price channel: firms in jurisdictions with more stringent carbon regulation are likely to reduce fuel use in response to that regulation, which can reduce the price of globally traded fossil fuels. These reductions in global energy prices would be expected to increase demand for these fuels in jurisdictions with less stringent regulations. This, in turn, will increase emissions in these jurisdictions.

Carbon leakage could be associated with negative economic, political, social and environmental impacts. It could undermine the carbon pricing's environmental objective by potentially increasing global emission levels. It could damage firm-level and national competitiveness compared to jurisdictions without a carbon price. Any decline in domestic production, investment and employment associated with carbon leakage can also create significant political and social challenges. This confluence of potentially undesirable outcomes makes carbon leakage one of the most controversial and important aspects of carbon pricing design.

Even though the ex-ante and ex-post literature is not conclusive, carbon leakage is only prevalent in a few distinct subsectors of the economy. Studies on carbon leakage risks prior to the introduction often find leakage rates to be high for some EITE industries. In contrast, evaluations after the implementation of carbon pricing policies suggest that competitiveness impacts have been marginal to non-existent. One main reason, apart from technical challenges to isolate the effect of a carbon policy, is that carbon prices have been low as a share of production costs. Furthermore, most carbon pricing schemes have some measures built in to mitigate carbon leakage.

Even though there is little previous evidence on economy-wide carbon leakage, impacts of carbon pricing on competitiveness and emissions need to be assessed for the particular economy and carbon pricing scheme. The composition of the economy, the role of different sectors in the global economy and the current technological advancements of the production process are relevant for the effects of carbon price. The actual design of the carbon pricing scheme, including the general ambition of emissions reduction and potential assistance mechanisms, is equally important.

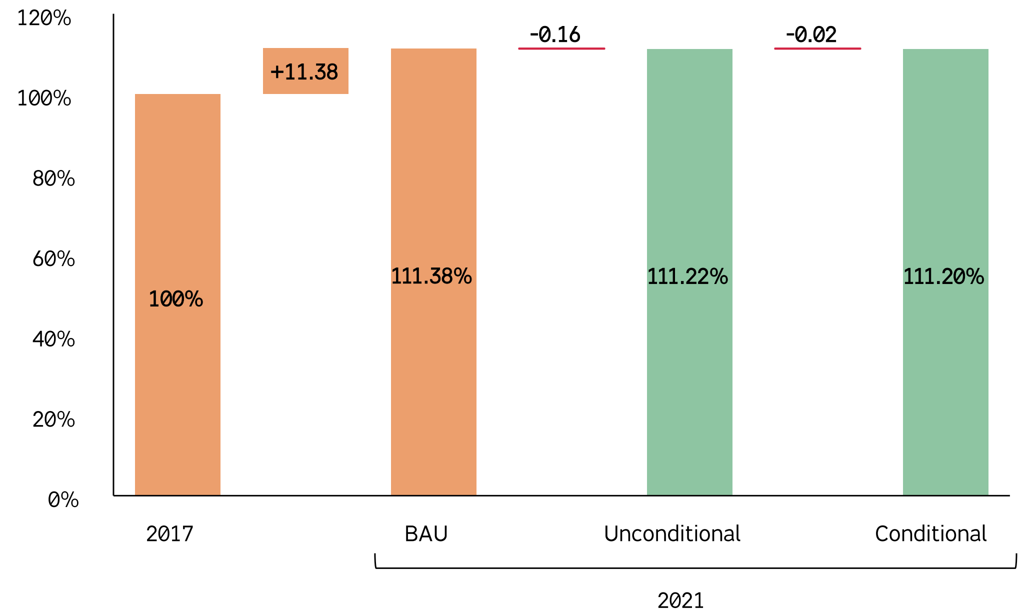
To understand carbon leakage risk in Mexico two approaches are used, an economy-wide and a sectoral analysis. The economy-wide one employs a computable general equilibrium (CGE) model to estimate effects of an ETS on the Mexican economy and some high-level sectors. The sectoral one uses international metrics to study carbon leakage risk based on current data of selected sub-sectors.

The economy-wide analysis estimates the impacts of the ETS both economy-wide and on key sectors. The Global Vivid Economy-Wide (GViEW) model is an economy-wide comparative static computable general equilibrium (CGE) model capable of analysing trade flows across multiple regions. The model simulates the production and flow of inputs between sectors and trade across regions. In order to estimate these effects, the model is set up to capture key attributes of Mexico's economy. Scenarios are also developed to model likely domestic and international climate policy developments, the main scenario includes the US dropping out of the Paris agreement.

Results suggest that the rate of economic growth is only marginally impacted by the ETS, and these figures do not account for broader environmental and economic benefits from abatement. In the main scenario the ETS reduces GDP growth by 0.16 percentage points (MXN44,000m) or MXN325 (USD18) per capita in 2021 compared to the BAU. Moving to the conditional NDC increases the cost of the ETS by MXN3,700m to MXN47,700m, which is an additional 0.02 percentage point reduction in GDP growth compared to BAU in 2021. Figure 1 displays the estimated effect of an ETS on GDP growth in Mexico. However, these figures do not account for co-benefits associated with mitigation, including reduced air pollution and improved energy security. Indeed, evidence suggests that Mexico can attain its substantial emission reductions at an economic gain when accounting for co-benefits.

On a sectoral level, the economy-wide analysis finds the chemical and plastic sector to be most negatively affected by the ETS. This sector includes the products of the chemical industry sub-sector from the sectoral analysis. Ferrous and non-ferrous metals and especially minerals see their exports increased, benefiting from higher carbon prices outside of Mexico.

Figure 1. The ETS is simulated to have little effect on GDP growth

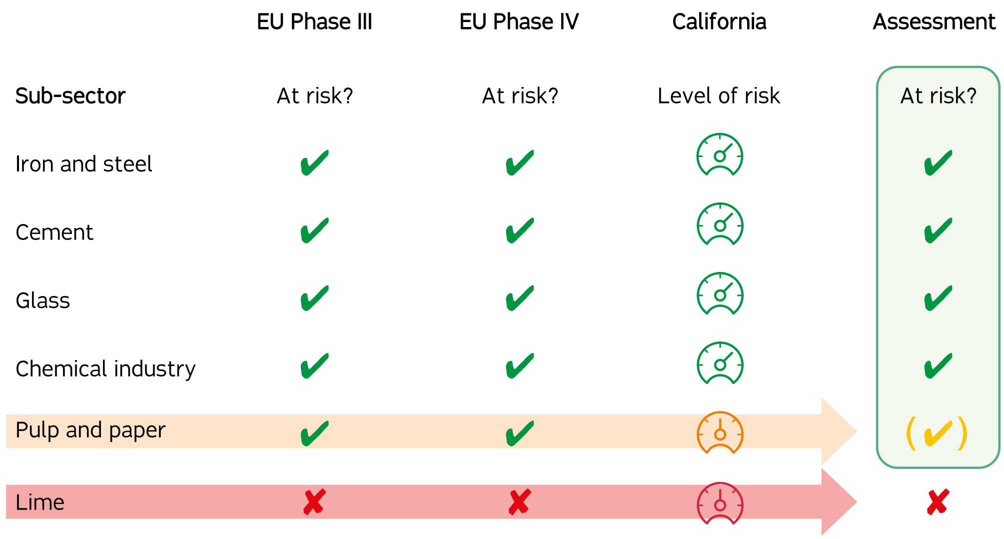


Note: The three estimated values for GDP represent the scenarios of no business as usual (BAU) and an ETS achieving the unconditional and conditional NDC.
Source: Vivid Economics

International metrics for the sectoral analysis use generally used two main metrics to estimate leakage risk: Trade intensity and (carbon) cost increase. Trade intensity is intended to capture the capacity of a firm to pass through carbon costs to consumers without losing profit margins or market share to international competitors. The cost increase metric is intended to capture a sub-sector's direct and indirect cost exposure to a carbon pricing mechanism. The sectoral analysis uses the EU ETS Phase III, EU ETS Phase IV and the Californian metric to estimate carbon leakage risk. Various sensitivity tests are performed to investigate how identification depends on assumptions. It is important to note that identification under an international indicator does imply that carbon leakage will necessarily occur, only that it is more likely than for sub-sectors not being identified.

The sectoral analysis finds iron and steel, glass, cement, and chemical industry ex ante at high risk of carbon leakage; pulp and paper's high risk to be not robust in sensitivity tests; and lime not at risk. The sub-sectors have been chosen due to the possible theoretical risk of carbon leakage and existing evidence related to these sub-sectors from previous research. The first four sub-sectors are identified to be at high risk under all three international metrics and the sensitivity tests do not change this assessment. The **pulp and paper** sub-sector is identified to be at risk under all metrics, but excluding indirect emissions changes the sub-sector's assessment under the Californian metric from high to medium. The **lime** sub-sector is not identified to be at risk under the EU Phase III and Phase IV indicator and classified at medium risk under the Californian metric. Figure 2 summarises the results of the quantitative sectoral analysis. The sector briefs in Appendix B additionally analyse cost pass-through capacity and carbon cost exposure to supplement the quantitative analysis. This qualitative analysis supplements the quantitative part of the sectoral analysis. The high market concentration in iron and steel, cement and parts of the chemical industry suggest carbon cost pass-through capacity, reducing the risk of carbon leakage. In the cement sub-sector, little international competition substantiates this conjecture and the comparison of its emissions intensity with other jurisdictions indicates that there is substantial abatement potential, further reducing the risk of carbon leakage.

Figure 2. Summary of sectoral analysis



Source: Vivid Economics

To prevent carbon leakage in vulnerable sub-sectors, this study recommends a gradual approach to target support better over time as the carbon market matures. Sophisticated mitigation policies will not be feasible from early on due to administrative burden, data availability and potential lack of political support.

The pilot and first phase could start with grandfathering before considering implementing a combination of output-based allocation and fixed-sector benchmarking in the future.
Grandfathering has little administrative requirements and can win over political support but will not be able to prevent leakage in the long term. Meanwhile, the Mexican government could use the Pilot Phase to gather more granular data and develop a national carbon leakage metric. In later stages, Mexico could introduce output-based allocation and fixed-sector benchmarking based on the developed metric. It would allow to mitigate carbon leakage in vulnerable subsectors in the long-term while preserving incentives introduced by the ETS to reduce GHG emissions.

The determination of which mechanism applies to each sector should be made on the basis of a comprehensive sub-sectoral carbon leakage risk assessment. The assessment of Mexican sub-sectors suggests the following distribution of allowances after the pilot phase:

- **Output-based allocation for iron and steel, cement, glass and chemical industry.** These sub-sectors are found to be at high carbon leakage risk across all indicators and sensitivity tests and require a strong mitigation policy with strong leakage prevention.

- **Fixed-sector benchmarking for pulp and paper.** This sub-sector is only found at medium risk under the Californian metric if indirect emissions are excluded. Fixed-sector benchmarking might be sufficient to prevent carbon leakage and would provide better abatement incentives than OBA.

- **Full auctioning for the lime sector.** This sub-sector is not at risk under 2 metrics and is not at high risk under the California metric. Thus it is unlikely to be at risk of leakage, principally due to low trade intensity. The application of free allowances could generate windfall profits or dilute abatement incentives.

Once an ETS has been operational for some time, Mexico could consider linking its carbon market to others to improve its performance. Regional and global cooperation on abatement are key pillars of the Paris Agreement, and could be attractive to Mexico at the later stages of ETS implementation. Once Mexico's ETS has been sufficiently developed, it could consider more technical international mechanisms to improve environmental, economic and political outcomes.

Resumen ejecutivo

En el marco del Acuerdo de París, México ha presentado objetivos ambiciosos para la reducción de gases de efecto invernadero (GEI). En la Contribución Nacionalmente Determinada (NDC por sus siglas en inglés), México anunció su intención de reducir las emisiones en un 22% respecto al escenario base *(business as usual-BAU)*. Se trata de un objetivo para toda la economía que abarca los GEI y que equivale a una reducción estimada de 210 $MtCO_2e$ para 2030. La NDC identifica que las actividades de reducción deberán llevarse a cabo en una amplia gama de sectores, incluido el sector industrial.

México pretende lograr que parte de la reducción de sus emisiones sea a través de un Sistema de Comercio de Emisiones (SCE), lo cual podría impactar de manera adversa la competitividad relativa, a nivel internacional, de los sectores intensivos en emisiones y expuestos al comercio (EITE por sus siglas en inglés). Ante la existencia de una importante asimetría en las políticas de carbono a nivel mundial, en el corto plazo, se podrá observar que la introducción de los precios del carbono en México incrementará los costos de producción en muchos sectores. Esto en comparación con sus pares internacionales que no han introducido la fijación de precios del carbono.

Como resultado de la asimetría en la fijación de precios del carbono entre jurisdicciones, se podría provocar una fuga de carbono, que ocurre cuando la actividad económica se traslada a otra jurisdicción. La fijación de precios del carbono podría aumentar en el corto plazo los costos de producción de las empresas mexicanas. Si el aumento de los costos es sustancial y la competencia internacional es fuerte, esto podría conducir a una pérdida de producción para las empresas en jurisdicciones sin políticas de fijación de precios de carbono, o con políticas menos estrictas. La fuga de carbono consiste en que algunas, o todas las reducciones de emisiones logradas en el país, podrían compensarse con mayores emisiones en otros lugares.

Existen tres canales clave a través de los cuales puede ocurrir una fuga de carbono:

1. El canal de producción o de competitividad a corto plazo opera a través de decisiones de producción distorsionadas: los mayores costos de emisión de carbono pueden hacer que las empresas afectadas por la fijación de precios del carbono, pierdan participación en el mercado en beneficio de las que no están cubiertas por la fijación de precios del carbono.
2. La inversión o el canal de competitividad a largo plazo: los diferentes precios del carbono alteran las decisiones de inversión entre los países. En el mediano plazo, esto puede ocurrir a través de una inversión reducida en capital de mantenimiento. En el largo plazo, las plantas existentes en jurisdicciones con regulaciones más estrictas de carbono pueden cerrarse y/o reubicar nuevas plantas en jurisdicciones sin fijación de precios de carbono (o con precios menos estrictos).
3. El canal de precios de los combustibles fósiles: las empresas en jurisdicciones con regulaciones de carbono más estrictas posiblemente reduzcan el uso de combustible en respuesta a esa regulación, lo que puede reducir el precio de los combustibles fósiles comercializados a nivel mundial. Se esperaría que dichas reducciones en los precios globales de energía, aumenten la demanda de estos combustibles en jurisdicciones con regulaciones menos estrictas. A su vez, esto aumentará las emisiones en esas jurisdicciones.

La fuga de carbono podría estar asociada con impactos económicos, políticos, sociales y ambientales negativos. Esto podría afectar tanto el objetivo ambiental de fijación de precios del carbono al aumentar potencialmente los niveles de emisión globales. De igual forma se podría dañar la competitividad a nivel de empresa y nacional en comparación con las jurisdicciones sin un precio de carbono. Cualquier disminución en la producción nacional, la inversión y el empleo asociados con la fuga de carbono, también pueden crear importantes desafíos políticos y sociales. Esta confluencia de resultados potencialmente indeseables, hace que la fuga de carbono sea uno de los aspectos más controvertidos e importantes del diseño de fijación de precios del carbono.

Si bien la literatura ex–ante y ex-post no es concluyente, la fuga de carbono solo prevalece en algunos subsectores de la economía. Los estudios ex–ante sobre los riesgos de fuga de carbono a menudo encuentran que las tasas de fuga son altas para algunas industrias EITE. Por el contrario, las evaluaciones ex-post sugieren que los impactos de la competitividad han sido marginales o incluso inexistentes. Una de las principales razones, más allá de los desafíos técnicos para aislar el efecto de una política de carbono, es que los precios del carbono se han mantenido bajos como parte de los costos de producción. Además, la mayoría de los esquemas de fijación de precios del carbono incorporan algunas medidas para mitigar las fugas de carbono.

A pesar de que existe poca evidencia sobre la fuga de carbono en toda la economía, los impactos de los precios del carbono en materia de competitividad y emisiones deben evaluarse para los esquemas particulares de fijación de precios de la economía y carbono. La composición de la economía, el papel de los diferentes sectores en la economía global y los avances tecnológicos actuales del proceso de producción, son relevantes para los efectos del precio del carbono. Resulta igualmente importante, tanto el diseño actual del esquema de fijación de precios del carbono, incluida la meta general de reducción de emisiones, como los posibles mecanismos de asistencia.

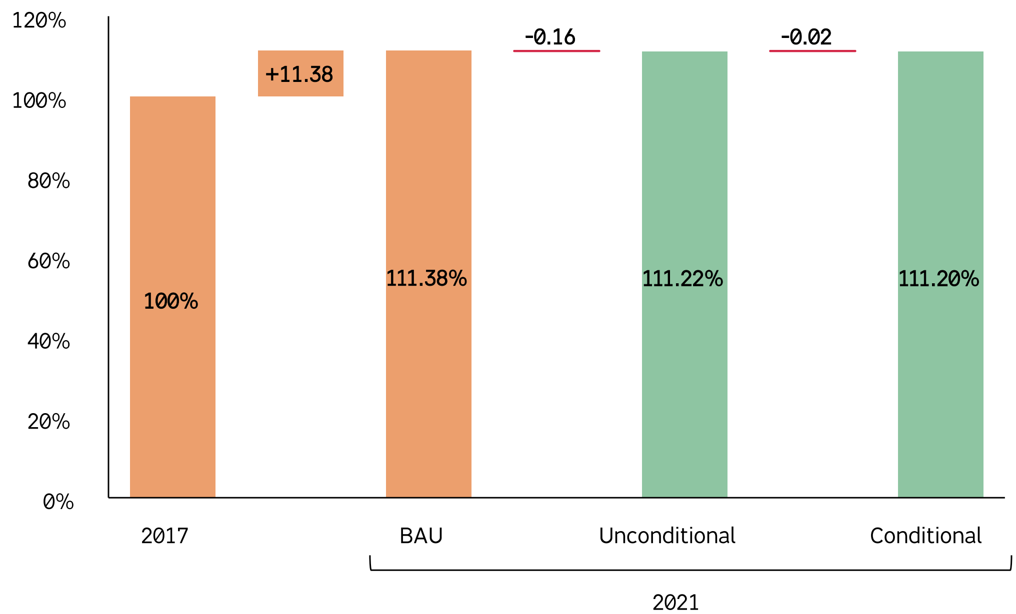
Para entender el riesgo de fuga de carbono en México se utilizan dos enfoques, un análisis de toda la economía y uno sectorial. El de toda la economía emplea un modelo de equilibrio general computable (EGC) para estimar los efectos de un SCE en la economía mexicana y en algunos sectores de alto nivel. El sectorial utiliza métricas internacionales para estudiar el riesgo de fuga de carbono en función de los datos actuales de los subsectores seleccionados.

El análisis de toda la economía estima los impactos del SCE tanto en toda la economía como en sectores clave. El modelo Global Vivid Economy-Wide (GViEW) es un modelo de equilibrio general computable estático (CGE) comparativo de toda la economía capaz de analizar los flujos comerciales en múltiples regiones. El modelo simula la producción, flujo de insumos y comercio entre regiones. Para estimar estos efectos, el modelo está configurado para considerar factores clave de la economía mexicana. Los escenarios también se desarrollan para modelar posibles desarrollos de políticas climáticas nacionales e internacionales. El escenario principal incluye la salida de los Estados Unidos de América del Acuerdo de París.

Los resultados indican que la tasa de crecimiento económico solo se ve afectada marginalmente por el SCE, y las cifras no toman en cuenta los beneficios medioambientales y económicos más amplios derivados de la reducción. En el escenario principal, el SCE reduce el crecimiento del PIB en 0.16 puntos porcentuales (MXN44,000m) o MXN325 (USD18) per cápita en 2021, en comparación con el BAU. Pasar al NDC condicional aumenta el costo del SCE en MXN3,700m, es decir, a MXN47,700m, que es una reducción adicional de 0.02 puntos porcentuales en el crecimiento del PIB en comparación con el BAU en 2021. La Figura 1 muestra el efecto estimado de un SCE en el crecimiento del PIB en México. Sin embargo, estas cifras no representan los co-beneficios asociados con la mitigación, incluida la reducción de la contaminación del aire y la mejora de la seguridad energética. De hecho, la evidencia sugiere que México puede lograr reducciones sustanciales de sus emisiones con un beneficio económico al contabilizar los beneficios colaterales.

A nivel sectorial, el análisis de toda la economía ha encontrado que el sector químico y del plástico son los más afectado por el SCE. Este sector incluye los productos del subsector de la industria química del análisis sectorial. Los metales ferrosos y no ferrosos, y especialmente los minerales, aumentan sus exportaciones, beneficiándose de los mayores precios del carbono fuera de México.

Figura 1. Simulaciones demuestran que el SCE no impacta el PIB de gran manera



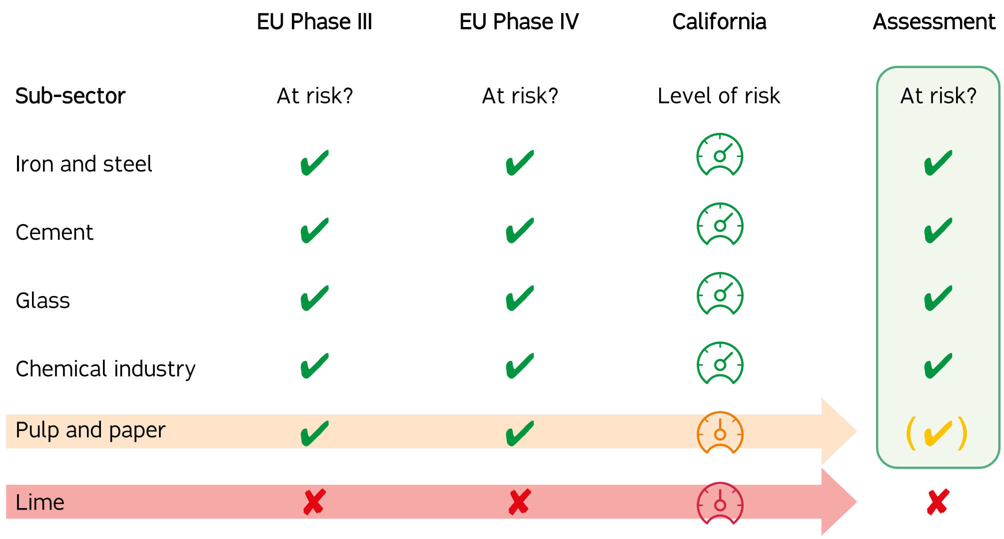
Nota: Los tres valores estimados del PIB representan los tres escenarios no base y el de un SCE cumpliendo con las incondicionales y condicionales metas NDC

Fuente: Vivid Economics

Las métricas internacionales para el análisis sectorial utilizan dos parámetros principales para estimar el riesgo de fugas: intensidad del comercio y aumento del costo (de carbono). La intensidad del comercio tiene la intención de capturar la capacidad de una empresa para pasar los costos del carbono a los consumidores, pero sin perder los márgenes de ganancia o la participación en el mercado frente a los competidores internacionales. El objetivo de la métrica de aumento de los costos es reflejar la exposición a los costos directos e indirectos de un subsector a un mecanismo de fijación de precios del carbono. El análisis sectorial utiliza la Fase III del SCE de la Unión Europea (UE), la Fase IV del SCE de la UE y la métrica californiana para estimar el riesgo de fuga de carbono. Se realizan varias pruebas de sensibilidad para investigar cómo la identificación depende de las estimaciones. Es importante tener en cuenta que la identificación bajo un indicador internacional implica que se producirá una fuga de carbono, pero es muy probable que no se identifiquen por subsectores.

El análisis sectorial ex–ante encuentra un alto riesgo de fuga de carbono en las industrias del hierro y acero, vidrio, cemento y la industria química; que el riesgo de fuga en la industria de pulpa y papel resulto no es robusto a las pruebas de sensibilidad; y que la industria de la cal no está en riesgo. Los subsectores se han elegido de acuerdo al posible riesgo teórico de fuga de carbono y la evidencia de investigaciones anteriores relacionada con estos subsectores. Los primeros cuatro subsectores están identificados como de alto riesgo con las tres métricas internacionales, asimismo, las pruebas de sensibilidad no cambiaron la evaluación. El subsector de **celulosa y papel** está identificado en riesgo ante todas las métricas, pero la exclusión de emisiones indirectas cambia la evaluación del subsector de alta a media con la métrica californiana. El subsector de la cal no se identificó en riesgo bajo los indicadores de la Fase III y Fase IV de la UE y se clasificó en riesgo medio en la métrica californiana. La Figura 2 resume los resultados del análisis sectorial cuantitativo. Los resúmenes sectoriales en el Apéndice B, analizan la capacidad de transferencia de costos y la exposición al costo del carbono para complementar el análisis cuantitativo. Por su parte, el análisis cualitativo complementa la parte cuantitativa del análisis sectorial. La alta concentración de mercado en hierro y acero, cemento y partes de la industria química sugieren una capacidad de paso de carbono, reduciendo el riesgo de fuga de carbono. En el subsector del cemento, poca competencia internacional corrobora esta conjetura, mientras que la comparación de la intensidad de sus emisiones con otras jurisdicciones, indica que existe un potencial de reducción sustancial, lo que reduce aún más el riesgo de fuga de carbono.

Figura 2. Resumen de análisis sectorial



Fuente: Vivid Economics

Para evitar la fuga de carbono en subsectores que son vulnerables, este estudio recomienda un enfoque gradual para orientar el apoyo a lo largo del tiempo, a medida que el mercado de carbono madure. Las sofisticadas políticas de mitigación no serán viables desde el principio debido a la carga administrativa, la disponibilidad de datos y la posible falta de apoyo político.

El piloto y la primera fase podrían comenzar con un esquema de derechos adquiridos, antes de considerar la implementación de una combinación de asignación basada en resultados y evaluación comparativa del sector fijo en el futuro. El esquema de derechos adquiridos tiene pocos requisitos administrativos y puede ganar el apoyo político, pero no podrá evitar fugas en el largo plazo. Mientras tanto, el gobierno de México podría utilizar la fase piloto para recopilar datos más detallados y desarrollar una métrica nacional de fugas de carbono. En etapas posteriores, México podría introducir una asignación basada en resultados y una evaluación comparativa del sector fijo basada en la métrica desarrollada. Esto permitiría mitigar la fuga de carbono en subsectores vulnerables a largo plazo, al tiempo que se mantendrían los incentivos introducidos por el SCE para reducir las emisiones de GEI.

La determinación del mecanismo que se debe aplicar a cada sector se tendría que hacer sobre la base de una evaluación amplia de los riesgos de fuga de carbono subsectoriales. Tras la realización de la fase piloto, la evaluación de los subsectores mexicanos sugiere la siguiente distribución de derechos:

- **Asignación basada en la producción para hierro y acero, cemento, vidrio e industria química.** Estos subsectores tienen un alto riesgo de fuga de carbono en todos los indicadores y pruebas de sensibilidad y requieren una fuerte política de mitigación con una fuerte prevención de fugas.

- **Evaluación comparativa del sector fijo para celulosa y papel.** Este subsector solo se encuentra en riesgo medio bajo la métrica californiana si se excluyen las emisiones indirectas. La evaluación comparativa del sector fijo podría ser suficiente para evitar la fuga de carbono y proporcionaría mejores incentivos de reducción que OBA.

- **Subasta completa para el sector de la cal.** Este subsector no está en riesgo en dos métricas y, según la métrica de California, no está en riesgo alto. Por lo tanto, es poco probable que corra riesgo de fugas, principalmente debido a la baja intensidad del comercio. La aplicación de asignaciones gratuitas podría generar ganancias extraordinarias o diluir los incentivos de mitigación.

Una vez que un SCE haya operado por algún tiempo, México podría considerar vincular su mercado de carbono con otros para mejorar su desempeño. La cooperación regional y mundial para la reducción, es un pilar fundamental del Acuerdo de París y podría ser atractivo para México en las etapas posteriores para la implementación del SCE. Una vez que el SCE de México haya sido suficientemente desarrollado, podría considerar mecanismos internacionales más técnicos para mejorar los resultados ambientales, económicos y políticos.

1

Introduction

1. Introduction

Under the Paris Agreement, Mexico has submitted ambitious greenhouse gas (GHG) reduction targets. In its Nationally Determined Contribution (NDC), Mexico announced its intention to reduce emissions by 22% relative to BAU. This is an economy-wide target covering all GHGs and is estimated to be equivalent to a reduction of 210 $MtCO_2e$ by 2030. The NDC identifies activities will need to be undertaken across a wide range of sectors including the industrial sector.

The implementation of abatement activities will require a comprehensive policy suite. Existing policies in this regard include: the reduction of fossil fuels subsidies, a carbon tax and the creation of the Climate Change Fund. Each of these policies is aligned with the current legal framework: The National Strategy on Climate Change, the Special Program of Climate Change, the Energy Transition Law, the General Law on Climate Change (LGCC) and the National Program for the Sustainable Use of Energy.

Importantly, the LGCC requires giving priority to the least costly mitigation actions which also promote and sustain the competitiveness of the vital sectors of the economy. Under the LGCC, Mexico has implemented a National Emissions Registry (RENE), which requires all entities emitting in 29 excess of 25,000 tCO_2e/year to submit annual reports on their emissions of seven categories of GHGs and black carbon, subject to verification every three years. Extending to direct and indirect emissions from stationary and mobile sources, RENE covers all major sectors including energy, transport, agriculture, services, industry, construction, tourism and government, and thereby provides a critical basis of information for carbon pricing(GIZ 2017a).

Part of the emissions reduction is planned to be achieved through an Emissions Trading Scheme (ETS), which is scheduled to start its Pilot Phase in 2019. The Mexican Senate passed a bill that gives the mandate for ETS implementation in April unanimously. A market simulation has already started in October 2017 and lasts for 10 months. The Pilot Phase is expected to begin in late 2018 and concludes in 2021. Afterwards, the mandatory phase is likely to start.

Part of the emissions reduction is planned to be achieved through an Emissions Trading Scheme (ETS), which is scheduled to start its Pilot Phase in 2019.

However, the ETS may adversely impact the relative international competitiveness of Mexico's emission-intensive and trade-exposed (EITE) sectors. In a world of asymmetric carbon policies, the introduction of carbon pricing in Mexico could increase production costs for many sectors relative to international peers, at least in the short term. Depending on the nature of their exposure to a carbon price and the competitive environment they operate in, these sectors may be unable to pass through carbon costs without significant loss of market share.

Ultimately, this could result in carbon leakage, which occurs when economic activity relocates to another jurisdiction a result of asymmetries in carbon pricing. As firms in EITE sectors lose competitiveness, firms which do not face a domestic carbon constraint can increase market share. In the long run, returns to capital in the latter set of firms may increase, thus leading to investment to shift to countries without carbon pricing. Such shifts in production or investment could mean that lower emissions in Mexico are partly, or more than, offset by higher emissions in a less regulated region. In this case, the intended reduction in emissions would not be achieved at the global level.

Carbon leakage is particular concern for Mexico as the economy depends substantially on the industrial sector and international trade. In 2015, industry contributed 32% of Mexican GDP, well above the OECD average of 24% (World Bank 2018d). Furthermore, the Mexican economy is relatively trade intense, representing 72% of GDP in 2015, significantly above the OECD level of 56% (World Bank 2018c).

This report is intended to support policymakers in implementing comprehensive carbon policies while mitigating adverse effects on economic competitiveness. The challenge is to correct the issues caused by the lack of a global carbon price without jeopardising the benefits of market-based environmental policies. The key question which determines a successful design of policy instruments is whether firms still face incentives to reduce their emission intensity without damaging their international competitiveness. Once carbon leakage is identified and quantified, policy makers can address these environmental integrity and economic competitiveness concerns by appropriate policy responses.

This report identifies sectors at risk of carbon leakage, estimates competitiveness impacts and offers policy recommendations to manage and reduce carbon leakage risk. After discussing theoretical and empirical evidence of carbon leakage, different international metrics are used to analyse the carbon leakage risk of certain sub-sectors in the Mexican economy. This sectoral analysis is supplemented by an economy-wide simulation of the effects of a Mexican ETS on its economy and trade. The results from these analyses are then used to recommend tailored policy responses to mitigate carbon leakage risk under a Mexican ETS.

The remainder of this report is structured as follows:

– Section 2 introduces the theory of carbon leakage and presents ex-post and ex-ante evidence.

– Section 3 analyses carbon leakage risk in Mexico through two approaches; a sectoral analysis that assesses leakage risk for Mexican subsectors based on established international metrics using current official data, and an economy-wide analysis that employs a computable general equilibrium (CGE) model to simulate the effects of an ETS on the Mexican economy.

– Section 4 discusses policies to mitigate leakage risks.

– Section 5 concludes the report and provides policy recommendations for Mexico.

2

Theory and Evidence of Carbon Leakage

2. Theory and evidence of carbon leakage

2.1. Climate change and carbon pricing

To keep global warming well below 2 degrees Celsius, and avoid the severe social, economic and environmental impacts of climate change, a deep decarbonisation of the global economy is required. In 2016, 86 % of global primary energy supply was generated from carbon-intensive and non-renewable fossil fuels(1). Additionally, process emissions from activities such as manufacturing, agriculture and waste management contribute significantly to the world's atmospheric greenhouse gases (GHG) concentration. Growing emissions are driving dangerous climate change and action is required on a global scale in order to slow and reverse these trends.

As a result, almost all countries have pledged binding emission reduction targets in the Paris Agreement. The Agreement commits countries to paths for holding global climate change below 2 degrees Celsius by the end of the century. Each signatory country has developed a voluntary national plan for achieving climate policy goals, known as a Nationally Determined Contribution (NDC), in which they identify sector-specific policies and programmes they intend to implement to reduce emissions by 2030.

Implementing the Agreement requires policies which incentivise abatement. Within most economies, emissions intensive industries do not face the true costs of emitting GHGs. Private market incentives mean that the social costs of emissions are borne by neither businesses nor consumers. However, climate change damage is a burden on society. Thus, governments must implement a range of policies in order to ensure private agents face the right incentives for emissions abatement and so that environmental damage is averted.

Central to these policy options is carbon pricing, which is a way to achieve decarbonisation in a cost-effective and flexible way. The future of many decisive factors affecting production and abatement is uncertain. This includes technological development and innovation, prices for fossil fuels and renewables, and demand trends among others. Therefore, direct government regulation alone is unlikely to achieve decarbonisation efficiently: producers are unlikely to be able to access the information required to cover the complexity of emitting and abatement and their continual changes. Therefore, governments have introduced carbon pricing to achieve decarbonisation targets while also allowing private economic agents to flexibly respond to new information.

Carbon pricing incentivises upstream firms, intermediaries and end-users to supply and demand low-emissions goods and services. By pricing emissions, the external costs of the production and consumption of emissions-intensive goods are internalised into private costs. Firms will treat these costs like other business costs and aim to reduce them to increase profit margins and/or gain market share. In the medium and long term, low-emissions producers will gain market share over high-emissions producers. Equivalently, consumers will substitute towards low-emissions products due to their cost advantage. Therefore, carbon pricing is a critical part of a policy suite for the decarbonisation of the economy.

Carbon pricing incentivises upstream firms, intermediaries and end-users to supply and demand low-emissions goods and services.

81 parties to the Paris Agreement are planning or considering the use of carbon pricing to achieve their NDC. Jurisdictions accounting for about half of the global economy and more than a quarter of emissions are covered by carbon pricing initiatives as of 2017(2). In the medium or long term, most parts of the world are expected to be covered by emissions pricing instruments.

(1) Vivid Economics based on BP Statistical Review of World Energy 2017.
(2) World Bank (2017). State and Trends of Carbon Pricing 2017.

2.2. Carbon pricing and carbon leakage

In the absence of a globally harmonised carbon price, there is variation in countries' climate ambition and abatement speed. Some jurisdictions have relatively ambitious climate targets and have longstanding carbon pricing schemes, such as the EU and California. Other regions are at earlier stages of planning or implementing carbon pricing nationally, such as in Brazil, China and South Korea. Finally, some regions generally lack climate ambition and are highly unlikely to implement carbon pricing nationally in the near term, such as Saudi Arabia or the US at a federal level.

This variation gives rise to asymmetries in carbon pricing stringency between jurisdictions and thus to differences in compliance costs for the same industry in different locations. Carbon pricing, and more generally environmental regulation, increases the production costs of firms in the regulated jurisdiction at least in the short term. The role of production costs in competitiveness of a firm varies across sectors. In some sectors other factors are more important, such as the ability to innovate, increase product differentiation or react to changes in consumer preferences.

For many emissions-intense sectors however, cost bases are key elements of competitiveness and they operate in global markets.

– They often produce a relatively homogeneous good, such as cement or steel products. Thus customers are sensitive to price movements.

– Moreover, markets tend to be highly internationalised, and thus firms in these sectors tend to be price takers

As a result, in the absence of cheap abatement opportunities, carbon price increases may result in an inability to pass through costs without significant loss of market share.

As a result, these sectors are susceptible to carbon leakage, which occurs when carbon pricing induces production to shift to jurisdictions with less stringent carbon pricing. It occurs when a carbon price causes a reduction in emissions in the jurisdiction where it is implemented but inadvertently causes production to shift to jurisdictions with less ambitious emissions reduction policies. If the emissions intensity of production in jurisdictions that see an increase in production is greater than in jurisdictions where production falls, it is conceivable that this could lead to a net increase in global emissions.

It is crucial to note that this shift of emissions needs to be caused by a difference of stringency in emissions regulation. A mere change of emissions or output does not automatically qualify as carbon leakage. In a globalised world, production shifts due to various reasons and environmental compliance is only one factor in a firm's complex decision where to produce. This makes the ex-post observation and quantification of carbon leakage challenging. The counterfactual, how the firm would have produced in the absence of carbon regulation, remains unobservable.

There are three channels through which carbon leakage occurs (PMR 2015)[3]:

– **The output or short-term competitiveness channel:** a firm covered by carbon pricing could lose market share to an uncovered firm because of the difference in production costs due to carbon pricing. Changes in competitiveness are caused by asymmetric carbon pricing. This will lead to carbon leakage since emissions and production increase in the unregulated jurisdiction. If a covered firm loses market share to another covered firm because the latter is less emission intense, it does not account for carbon leakage but is the intention of the carbon pricing policy.

– **The investment or long-term competitiveness channel:** in the medium-to-long term investment decisions in maintaining or expanding capital might be altered due to differences in emissions regulations. In the medium term, firms might invest less in capital maintenance in covered regions and the resulting reduced efficiency would lead to reduced output, which might be taken up by uncovered firms. In the longer term, new plants might preferably be located in uncovered regions and/or existing plants in covered regions might be shut down.

(3) Carbon pricing may also lead to technological spillovers in the regulated jurisdiction and thus could improve covered firms' international competitiveness, leading to increases in output and investment.

– **The fossil fuel price channel:** carbon pricing should reduce demand for fossil fuels in covered regions, resulting in a fall in the price for fossil fuels globally. However, this might induce a rebound effect: the fall in price globally would increase demand for fossil fuels in uncovered regions, resulting in higher emissions in these areas and potentially higher emissions globally.

Carbon leakage potentially has undesirable environmental, economic, and political consequences and is therefore a major concern for policymakers and industry. There are three reasons for this:

1. **Carbon leakage could undermine the environmental objective of carbon pricing by causing emissions to increase in regions beyond the reach of the policy.** A shift of production and therefore emissions to an uncovered jurisdiction would lower a country's effective contribution to the reduction of global emissions. Since the gains of GHG emissions reduction materialise mostly on a global level this would jeopardise the overall benefits of the policy.
2. **Furthermore, carbon leakage raises the economic costs of reaching a certain emissions reduction objective.** First, to reach a certain global reduction the (indirect) carbon price must be higher when leakage occurs, increasing the compliance costs for covered firms. Second, the difference in carbon price between jurisdictions creates a distortion between competing firms, economically a reduction in social welfare compared to the undistorted case.
3. **At the same time, the decline in domestic production and employment can create significant political and social challenges.** Economic output and especially employment is a key objective for policymakers. If carbon pricing induces carbon leakage, it can cause economic decline an unemployment, which can induce significant social and political challenges. Leakage can therefore also reduce political support for carbon pricing.

This confluence of potentially undesirable outcomes makes leakage one of the most controversial and important aspects of carbon pricing design. The risk of carbon leakage results in industry actively lobbying for protection when carbon pricing mechanisms are being designed. Policymakers often react by facilitating stakeholder engagement and addressing competitiveness concerns by amending the instrument's design. Scientific studies can help to inform the public debate by estimating prospective or past carbon leakage.

2.3. Ex-ante and ex-post evidence of carbon leakage

In general, there are two distinct approaches to estimate carbon leakage:

– An ex-ante or theoretical approach where the effects of a carbon pricing policy are modelled before the (potential) implementation

– An ex-post approach where the effects of a carbon pricing policy are estimate after implementation.

Ex-ante approaches generally use either computable general equilibrium (CGE) or partial equilibrium models to estimate risk of carbon leakage. In general, CGE models find relatively low levels of carbon leakage, while partial equilibrium models estimate higher rates and higher variation in rates. One reason for the structural difference in results is that partial equilibrium models assume perfect substitutability between domestic and foreign goods and therefore economies are more vulnerable to changes in costs by design. By contrast, CGE models use trade elasticities to account for intangible trade barriers, and also account for dynamic shifts between sectors. A third methodology has emerged in recent years which first estimates the historic relationship between energy prices and trade and production econometrically and then extrapolates these estimates for carbon prices.

Ex-post approaches generally find little to no evidence of carbon leakage. These empirical evaluations employ econometric techniques to isolate the effect of carbon pricing from other prevalent developments. Competitiveness effects are found to be mild and even in cases where regulated and unregulated firms are directly compared no significant impact was prevalent (Flues and Lutz 2015).

Some general caveats to the existing empirical research apply:

– **There is little data to study medium- and long-term effects as most carbon pricing schemes are relatively young.** This tends to overestimate carbon leakage as abatement options and innovations are more feasible in the medium- and long-term, while in the short term there might be fewer options to adapt production processes.

- **Most existing carbon pricing schemes are characterised by low prices.** Therefore the ex-post research only studies carbon leakage risk of moderate carbon prices and empirical evidence on competitiveness impacts of ambitious carbon pricing is barely available

- **Existing carbon pricing schemes have often incorporated some sort of carbon leakage mitigation policy, such as free allocation in the EU ETS.** Thus it is challenging to disentangle if carbon leakage does not occur because the mitigation policies are working or because carbon leakage is generally unlikely. This tends to underestimate carbon leakage if risk mitigation policies are not taken into account.

An overview of recent ex-ante and ex-post evidence of carbon leakage is displayed in Table 1.

Box 1 defines the presented carbon leakage rates.

Box 1. Carbon leakage is usually estimated in terms of a rate of leakage

When modelling carbon leakage, it is often helpful to define carbon leakage in terms of a carbon leakage rate. This is defined in terms of the increase in emissions in the jurisdiction without a carbon price (or with a lower carbon price/less stringent regulation) expressed as a percentage of the decrease in emissions in the jurisdiction with a (higher) carbon price (or more stringent regulation).

For instance, if the introduction (or further strengthening) of carbon pricing resulted in total carbon emissions in one country declining by 200 tonnes and foreign emissions increasing by 60 tonnes, the leakage rate would be calculated as 60 divided by 200, and expressed as 30 per cent. While policymakers will not always need to rely on formal estimates of carbon leakage rates in order to set policy, they can nonetheless be a useful analytical tool to understand differences between sectors, over time, or between different modelling analyses.

Table 1. Ex-ante and ex-post studies differ significantly in their findings on carbon leakage

	Ex-ante			Ex-post		
Sector	**Author**	**Scope**	**Carbon leakage rate**	**Author**	**Scope**	**Strong evidence of leakage**
Iron and steel	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price USD15	Output loss: 12% Employment loss: 8%	Boutabba and Lardic (2017)	Phases I and II and part of phase II of the EU ETS; 2005-2015	No
	Ritz (2009)	EU ETS; calibration 2003-2005; carbon price EUR20	9 to 75 (EU to ROW)	Branger, Quirion, and Chevallier (2017)	Phases I and II of the EU ETS; 2005-2012	No
	Santamaría, Linares, & Pintos (2014)	EU-ETS-covered part of steel in Spain; carbon price EUR5-35	18 to 95 (Spain to ROW)	Chan, Li, and Zhang (2013)	EU ETS before and after implementation; 2001-2009	No
				Bruyn, Markowska, and Nelissen (2010)	EU ETS; 2005-2009	No
				Ellerman, et al (2010)	Phase I of the EU ETS	No
Lime	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price USD15	Output loss: 10% Employment loss: 8%			
Cement	Allevi et al. (2013)	EU-ETS-covered part of cement (clinker) in Italy; carbon price EUR32-100	17 to 100 (Italy to ROW)	Boutabba and Lardic (2017)	Phases I and II and part of phase II of the EU ETS; 2005-2015	No
	Healy, Quirion, and Schumacher (2012)	U 2005-2012; grey clinker market; carbon price EUR20	22 (EU to ROW)	Branger, Quirion, and Chevallier (2017)	Phases I and II of the EU ETS; 2005-2012	No
	Szabó, Hidalgo, Ciscar, and Soria (2006)	European Union and Kyoto Protocol Annex B countries; 1990-1997; carbon price EUR28-40	Carbon leakage: 29; production leakage: 33 (EU and Annex B countries to ROW)	Chan, Li, and Zhang (2013)	EU ETS before and after implementation; 2001-2009	No
	Santamaría, Linares, and Pintos (2014)	EU-ETS-covered part of cement in Spain; carbon price EUR5-35	35 to 80 (Spain to ROW)	Ellerman, et al (2010)	Phase I of the EU ETS	No
	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price USD15	Output loss: 9% Employment loss: 6%			
Glass	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price USD15; class containers only	Output loss: 17% Employment loss: 13%	Oberndorfer, Alexeeva-Talebi, and Loschel (2010)	EU ETS on prices in UK manufacturing; 2001-2007; selected products only	Low cost pass-through indicates some effect on competitiveness

Table 1. Ex-ante and ex-post studies differ significantly in their findings on carbon leakage

	Ex-ante			Ex-post		
Sector	Author	Scope	Carbon leakage rate	Author	Scope	Strong evidence of leakage
Pulp and paper	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price USD15	Output loss: 14% Employment loss: 11%	Abrell, Zachmann, and Ndoye (2011)	EU ETS; 2005-2008	No
				Anger and Oberndorfer (2008)	EU ETS on competitiveness in Germany	No
				Yu (2013)	EU ETS on competitiveness in Sweden; 2004-2006	No
Chemical industry	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price USD15; only 'all other basic inorganic chemical manufacturing'	Output loss: 7% Employment loss: 4%	Bruyn, Markowska, and Nelissen (2010)	EU ETS; 2005-2009	No
				Oberndorfer, Alexeeva-Talebi, and Loschel (2010)	EU ETS on prices in UK manufacturing; 2001-2007; selected products only	No
				Yu (2011)	EU ETS on competitiveness in Sweden; 2004-2006	No

Note: Sector definitions might not exactly align with the granularity used in the sectoral analysis in Section 3.2
Source: Vivid Economics

Even though the ex-ante and ex-post literature is not conclusive, carbon leakage is, if that, only prevalent in a few distinct subsectors of the economy. There is certainly no evidence on a large-scale shift of economic activity, employment or emissions as claimed by some opponents of carbon pricing. Some emission- and trade-intense sectors are occasionally found to be impacted, but even for these industries results are not universal.

A main reason for the low occurrence of carbon leakage is that the costs of environmental compliance are only one factor in the multidimensional production decision. First, purchasing emission permits or paying a carbon tax is only one part of the production costs and other contributors such as resource prices or labour costs are often more significant. In addition, firms have long been observed to not only compete in costs, but in the efficiency of converting inputs into high-value outputs. In this process, factors such as access to a qualified labour force, stable institutions, and innovation and technological development are often more important than mere cost competition. These findings are in line with a large body of research on the effects of environmental policies[(4)].

Even though the empirical evidence in this case is not conclusive either, the argument that environmental regulations compromise firms' or sectors' competitiveness on a large scale is regularly rejected. Empirical research does not find evidence for such claims (Ambec et al. 2013; Dechezleprêtre and Sato 2017). Mexican policy makers and stakeholders do not need to be concerned about a significant and economy-wide move of employment, production and emissions to uncovered jurisdictions as there is no evidence supporting this claim.

The composition of the economy, the role of different sectors in the global economy and the current technological advancements of the production process are relevant for the effects of carbon price.

Even though there is little previous evidence on economy-wide carbon leakage, impacts of carbon pricing on competitiveness and emissions need to be assessed for the particular economy and carbon pricing scheme. The composition of the economy, the role of different sectors in the global economy and the current technological advancements of the production process are relevant for the effects of carbon price. The actual design of the carbon pricing scheme, including the general ambition of emissions reduction and potential assistance mechanisms, is equally important.

(4) The Porter Hypothesis goes even further. It states that the costs of well-designed environmental regulation for firms is often offset or even outweighed by medium- or long-term benefits arising from efficiency improvements and higher levels of innovation.

3

Carbon Leakage Risk and Competitiveness Analysis

3. Carbon leakage risk and competitiveness analysis

In order to provide a holistic understanding of carbon leakage risk, this section offers both an economy-wide and a sectoral perspective. The economy-wide analysis employs a computable general equilibrium (CGE) model to estimate the effects of an ETS on the Mexican economy and competitiveness impacts on four highly aggregated sectors. The sectoral analysis uses international metrics to estimate carbon leakage risk for six industrial sub-sectors. The structure is as follows:

– Section 3.1 summarises the results of the economy-wide analysis, including a description of the methodology and model set up.

– Section 3.2 presents the sectoral analysis, including the methodology and sensitivity analysis for each sub-sector.

3.1. Economy-wide analysis

3.1.1. Methodology

The economy-wide model estimates the impacts of the ETS both economy-wide and on key sectors. The model simulates the production and flow of inputs between sectors and trade across regions. In order to estimate these effects, the model is set up to capture key attributes of Mexico's economy. Scenarios are also developed to model likely domestic and international climate policy developments.

This section presents the economy-wide modelling methodology:

– 3.1.1.1 **Model set up:** presents how the model is calibrated to Mexico's economy and how regions of the world are aggregated;

– 3.1.1.2 **Scenarios:** details the set of domestic and international climate policies that combined represent a range of ambition scenarios for reducing emissions;

– 3.1.1.3 **How to interpret results:** relays important caveats to the results and discusses how to interpret economy-wide numbers.

Detailed modelling methodology is provided in the Appendix.

3.1.1.1. Model set up

The Global Vivid Economy-Wide (GViEW) model is an economy-wide comparative static computable general equilibrium (CGE) model capable of analysing trade flows across multiple regions. It is economy-wide in the sense that it models relatively large parts of the economy, such as sectors, as single units based on patterns in their aggregate behaviour. It sets up a coherent framework to simulate the functioning of a market economy by examining the production and trade relationships between different sectors. It is precisely these intersectoral relationships which allow CGE models to estimate the indirect impact of policies. The model encompasses multiple specified regions and can assess trade flows between regions with diverging climate policies. It models energy production, carbon dioxide emissions, trade and investment as well as interactions between these flows. However, the model is incapable of disaggregating policy impacts at the firm level. The model is nevertheless useful for policy makers as it estimates the pace and path of Mexico's economy under different policy scenarios at a high-level. Box 2 presents GVIEW's advantages and disadvantages.

Box 2. GVIEW advantages and disadvantages

In the context of this project, GViEW has several advantages relative to bottom-up or technological sectoral models due to both the types of results it can generate and its practicality:

- ✓ Adept at modelling economy-wide, trade flows and inter-sectoral impacts of policies;
- ✓ Captures feedback loops and indirect effects of policy interventions;
- ✓ The majority of required data is readily available from the GTAP database;
- ✓ Relatively low data demands and results are more robust to lower quality data.

However, GViEW also has several disadvantages which are important to bear in mind when interpreting the results:

- ✗ The nature of the modelling language and set-up can make it challenging to inspect and scrutinise assumptions;
- ✗ The model simplifies the economy into representative agents that may behave differently than actual economic agents;
- ✗ Some assumptions may be unrealistic in the short term, for example, that prices quickly adjust to ensure demand equals supply in all markets.

In the Mexico calibration, aggregates of regions and sectors are constructed to reflect the production and flow of inputs in Mexico's economy. The model is calibrated to cover specific greenhouse gases (GHGs), apply the ETS to emissions intensive sectors, allocate the ETS certificates under a certain design and report outputs for 2021, the first year of the ETS. The Mexico calibration of the model is as follows:

- **Regions:** the regional aggregation is calibrated to capture Mexico's primary import and export destinations (the United States, Canada, China, the European Union) and remaining countries are aggregated into the rest of the world (ROW) region. The United States, Canada, China and the European Union represent more than 90% of Mexico's export destinations by value (The Observatory of Economic Complexity 2018a).
- **Sectors:** the four key sectors in the model aggregation include non-metallic minerals, ferrous metals, non-ferrous metals and chemicals and plastics. Within these high-level aggregations are five of the six sectors (cement, lime, glass, iron and steel, and chemicals) covered in the sectoral analysis. These sectors are both emissions-intensive, trade-exposed (EITE) and are likely covered by the ETS. Paper and pulp is not included in the economy-wide analysis as it is grouped into 'other manufacturing' in the economy-wide model aggregation.
- **Gases:** The model is set up to cover emissions from CO_2 only, which are a majority of Mexico's emissions. Emissions from CO_2 include emissions from combustion and process emissions.
- **ETS coverage:** The ETS covers the four key sectors listed above and the electricity sector to achieve their proportionate share of the NDC path in 2021.
- **Allocation method:** the model allocates free allowances on a grandfathering approach, where allocations are proportional to a sector's historical emissions and there is no adjustment in allocation if firms change their output.
- **GDP:** The model requires GDP forecasts as an input to estimate the pace of GDP growth without policy interventions. Mexico's GDP growth is set to 2.7% per year in line with OECD long run GDP forecasts. Annual GDP growth forecasts for Mexico's trade partners can be found in Appendix C.
- **Year:** The model simulates the functioning of Mexico's economy for the year 2021, the first year of the proposed ETS.

Table 2 presents the model setup for simulating the economic impacts of the ETS in 2021. Detailed modelling methodology can be found in Appendix C.

Table 2. Set-up for economy-wide model

Category	Aggregation/calibration	Description
Regions	**Mexico**	
	USA	The US is the main trade partner of Mexico, accounting for 47% of Mexican imports and 81% of Mexican exports in 2016 (The Observatory of Economic Complexity 2018b)
	Canada	Canada is a separate region as it is also part of NAFTA
	European Union	The EU is a significant trading partne
	China	China is the top import origin and a key competitor
	Rest of world	All other countries are aggregated to 'rest of the world' to reduce the complexity of the model
Sectors	**Non-metallic minerals ('minerals')**	**Cement,** plaster, **lime**, gravel, concrete, **glass** and ceramics
	Ferrous metals	**Iron and steel**, basic production and casting
	Non-ferrous metals	Production and casting of copper, aluminium, zinc, lead, gold, and silver
	Chemicals and plastics	**Basic chemicals, other chemical products,** rubber and **plastic products**
Gases	**CO_2 emissions from combustion**	Only CO_2 emissions are covered, other GHGs are not
	CO_2 process emissions	CO_2 process emissions arising from industrial production
Allocation method	**Grandfathering**	Free allocations are proportional to a sector's historical emissions
GDP growth	**Mexico**	2.7% per year to 2021 under BAU conditions (OECD 2018a)
Year	**2021**	The first year of the proposed ETS

Note: Bolded sectors are covered in the sectoral analysis
Source: Vivid Economics

3.1.1.2. Scenarios

In order to estimate the impact of the ETS, the model simulates the pace and path of the economy according to a set of imposed policy interventions throughout the global economy. There are two scenario levers:

– Mexico's ambition varies by whether its ETS places it on track in 2021 to meet either its unconditional or conditional NDC target.

– International ambition varies by whether all countries are on track to meet their NDC targets in 2021 or where all countries are on track except for the United States.

Table 3 summarises the four possible policy scenarios. A most likely, 'main' scenario is constructed by combining the most likely scenario levers. The main scenario serves as the focal point of the economy-wide analysis and is the scenario for which key sector results are presented.

Table 3. Mexico modelling policy scenarios

		International Ambition	
		US out of Paris	**All in Paris**
Mexico Ambition	**Unconditional**	Main Scenario	Paris Agreement Success
	Conditional	Increased Ambition	Maximum Ambition

Note: The maximum ambition scenario is not presented in this report as it is judged the least likely scenario given policy announcements.
Source: Vivid Economics

The main scenario is where Mexico and all other countries move to meet their unconditional NDC targets, but the US does not. Given US policy announcements and the Trump administration's decision to begin the withdrawal process from the Paris Agreement, this presents a most-likely scenario. Due to Mexico's close trade relationship with the United States, the US' decision to remain in or leave Paris is the most important international climate policy factor facing Mexico.

A baseline business-as-usual (BAU) scenario is constructed to compare the economic impacts of the main scenario. In the BAU scenario, all regions follow their forecasted growth paths without the introduction of an ETS. As a result, there are no economy-wide or sector impacts from the introduction of an ETS in any region in the BAU scenario, instead the pace and path of the economy progresses in business-as-usual fashion.

Where informative, we also present two additional scenarios. One scenario is based on Mexico meeting its conditional NDC target and the US remaining outside of the Paris agreement and another where all countries, including the US, adhere to the Paris Agreement. These scenarios only assess the impacts of the ETS at the macroeconomic level.

3.1.1.3. How to interpret results

Results are expressed as a comparison to the BAU scenario and are net impacts for a sector or region. A positive net effect contains both growth and leakage, potentially obscuring the full scale of leakage. Sectors are represented as single units based on aggregate behaviour. Specific subsectors within the large aggregated sectors reported by the economy-wide modelling are difficult to isolate and better suited for sectoral-up analysis. Deciding to relocate production for an individual firm is a decision that transcends climate policy and individual firm decisions are not captured by the model.

Sector assessments of carbon leakage by the economy-wide model help identify sectors for further sectoral analysis. The economy-wide model excels at identifying aggregate changes in trade relationships and high-level sector changes, producing evidence of where carbon leakage may take place. In this sense, economy-wide assessments are useful, though not sufficient, to determine whether a sector is at risk of carbon leakage. The ultimate determination of carbon leakage risk depends on confirmation in the sectoral analysis.

The economy-wide modelling is calibrated to assume that countries will move in 2021 to a path consistent with their NDC commitments. GDP, trade and GVA effects would change if countries move slower or later than 2021 to get emissions on a trajectory consistent with their 2030 NDC targets. Any updates to announced 2030 NDC targets in Mexico and among Mexico's trading partners would also change GDP, trade and GVA impacts.

Results here do not account for broader environmental and economic benefits from abatement, which may cause the overall benefits from abatement to exceed the costs. GIZ (2017) notes that many studies suggest Mexico can achieve substantial emission reductions with a net negative cost. This is because many of the ways Mexico can reduce emissions, such as industrial efficiency standards, vehicle fuel economy standards, gas flaring abatement, waste recycling yield savings that over time exceed their initial costs. The results in this analysis also do not account for broader environmental and economic benefits from abatement, including improved air standards and energy security.

3.1.2. Results

The economy-wide model estimates the impacts of the ETS on GDP, trade and GVA. The model results contain the likely pace and path of Mexico's economy in 2021 following the introduction of the ETS under the main scenario. GDP impacts are estimated for three scenarios and key sector impacts for the main scenario.

This section presents the results of the economy-wide modelling, separated into:

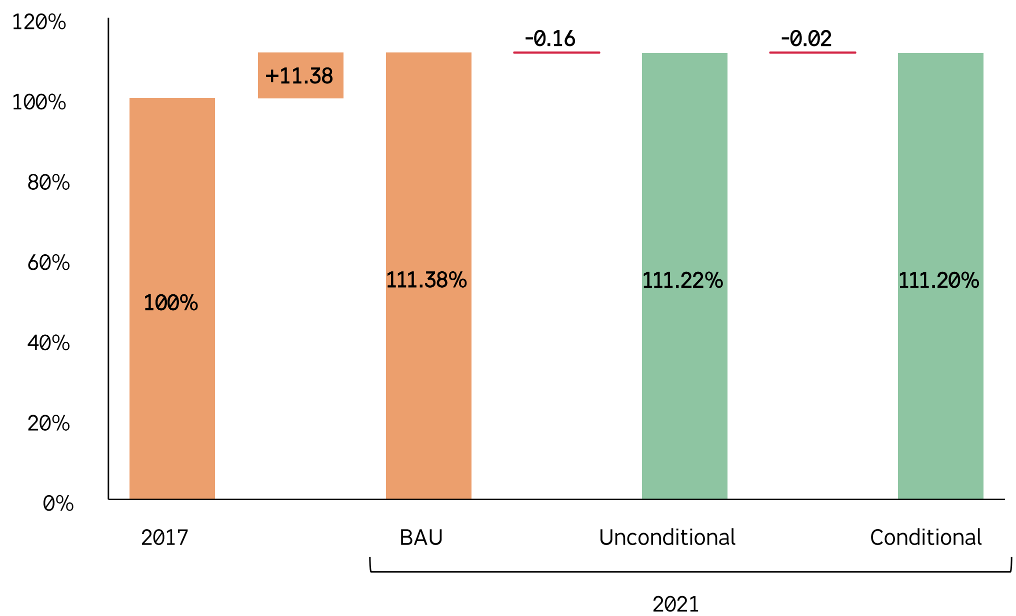
- 3.1.2.1 **Macroeconomic impacts:** examines the effects on GDP of implementing the ETS at different levels of ambition; and
- 3.1.2.2 **Trade and GVA impacts:** discusses the changes in the pattern of exports by destination and sector and sector changes in GVA.

3.1.2.1. Macroeconomic impacts

The rate of economic growth is only marginally reduced by the ETS. In the main scenario the ETS reduces GDP growth by 0.16 percentage points (MXN44,000m) or MXN325 (USD18) per capita in 2021 compared to the BAU.[5] Moving to the conditional NDC increases the cost of the ETS by MXN3,700m to MXN47,700m, which is an additional 0.02 percentage point reduction in GDP growth compared to BAU in 2021. The model does not take broader economic impacts and environmental benefits into account.

Under the ETS, Mexico's GDP is estimated to grow by 11.2% from 2017 to 2021 under both the unconditional and conditional NDC targets. If all countries, including the US, adhere to the Paris agreement, the ETS reduces GDP growth by 0.22 percentage points (MXN60,000m) or 0.06 percentage points more than the conditional NDC. Figure 3 presents the effect of the ETS on Mexico's GDP for the unconditional and conditional NDC targets.

Figure 3. GDP growth



Note: In the 'Paris' scenario, all countries adhere to the Paris agreement and meet their NDC targets. Mexico meets its unconditional NDC target.
Source: Vivid Economics

(5) The main scenario GDP reduction of MXN44,000m (compared to BAU) is divided by the 2021 World Bank population estimate of 135 million for Mexico. The exchange rate of MXN18.3 to USD1 is applied for the $US estimate and all results are rounded.

Mexico can meet its NDC at comparatively low cost by drawing on emissions reductions in sectors covered by the ETS. The economy-wide model estimates the electricity sector to deliver emissions reductions required to meet the NDC with marginal impacts to GDP. However, minor cost increases resulting from the ETS take place in key sectors at risk of carbon leakage, ranging from a 0.1% increase for chemicals and plastics to a 0.3% increase for ferrous metals.

• • •

Mexico can meet its NDC at comparatively low cost by drawing on emissions reductions in sectors covered by the ETS.

• • •

The unconditional NDC target translates into a 3% emissions reduction compared to BAU in 2021. This is a 10% increase in emissions from 2014 to 2021 that is consistent with a trajectory to meet the unconditional NDC target in 2030. The conditional target reduces emissions by a further 2% than the unconditional NDC (UNFCCC 2015a).

The limited divergence in emissions trajectories is a result of 2021 being the first year of the ETS, when only initial impacts occur. As the emissions cap continues to tighten in the mid-2020s, the divergence in emissions pathways (between the BAU, unconditional and conditional scenarios) widens. Consequently, the expectation is for the difference in GDP impacts by scenario to widen across time.

3.1.2.2. Trade and GVA impacts

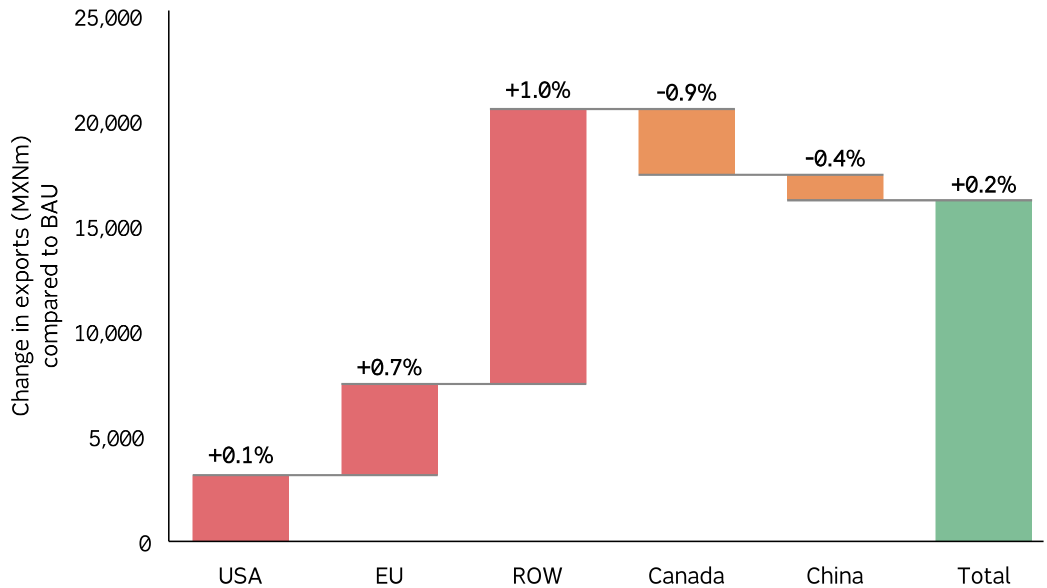
Mexico may export more overall compared to BAU as carbon prices in Mexico are lower than in the EU or ROW to meet NDC targets. Exports to the EU and ROW may increase as a result of carbon leakage from the EU and ROW to Mexico. In the main scenario, where the US leaves Paris, lower carbon prices in the US allow for increased US competitiveness by removing negative GDP effects and encouraging carbon leakage to the US. The result is stronger US GDP growth and greater US import demand that Mexico may benefit from. However, as a result of carbon leakage to the US, Mexico exports less overall to Canada and China as US exports replace exports from Mexico. Figure 4 depicts the change in Mexico's exports by destination.

The US dropping out of the Paris Agreement could raise US import demand, which could increase Mexican exports. By dropping out of the Paris Agreement, the US becomes more competitive compared to countries on-track to meet their NDC targets and the US does not experience the negative GDP impacts of implementing an ETS. This increased competitiveness may induce carbon leakage to the US as carbon intensive production relocates to the US, lifting US GDP and import demand. High US import demand lifts Mexico's exports to the US. This disproportionately benefits Mexico as a result of Mexico's close trade relationship with the United States where 81% of Mexico's exports by value were sent to the US in 2016 (The Observatory of Economic Complexity 2018b).

However, changes in exports predicted by the model depend on the continuation of existing trade deals, and the model does not account for other economic and environmental costs of the US withdrawing from the Agreement. The modelling does not simulate new trade relationships or account for potential trade retaliation resulting from the US dropping out of Paris. Moreover, there are a range of other costs which could arise for the US, and which could act to mitigate increased Mexican exports. These include:

- Reduced investment in the US as investors move to more sustainable portfolios;
- US goods could face international regulatory standards, resulting in a loss of competitiveness;
- The US falling behind other countries as a leader in key sustainable technologies.

Figure 4. Change in exports by destination



Note: Percentage change above bar is the percentage change in exports to destination compared to BAU.
Source: Vivid Economics

In the main scenario Mexico's exports are lifted for all key sectors except for chemicals and plastics compared to BAU. GVA changes mirror export changes in direction, though percentage changes differ. Figure 5 presents trade and GVA impacts relative to BAU. Export and GVA effects by sector and an assessment of carbon leakage risk from the economy-wide modelling follows:

- **Minerals:** exports increase substantially by almost 40%, though GVA impacts are smaller, increasing only 5.2% compared to BAU. This suggests minerals are likely to benefit from higher climate policy costs in other regions and increased import demand from the US. This implies considerable carbon leakage from other regions to Mexico.

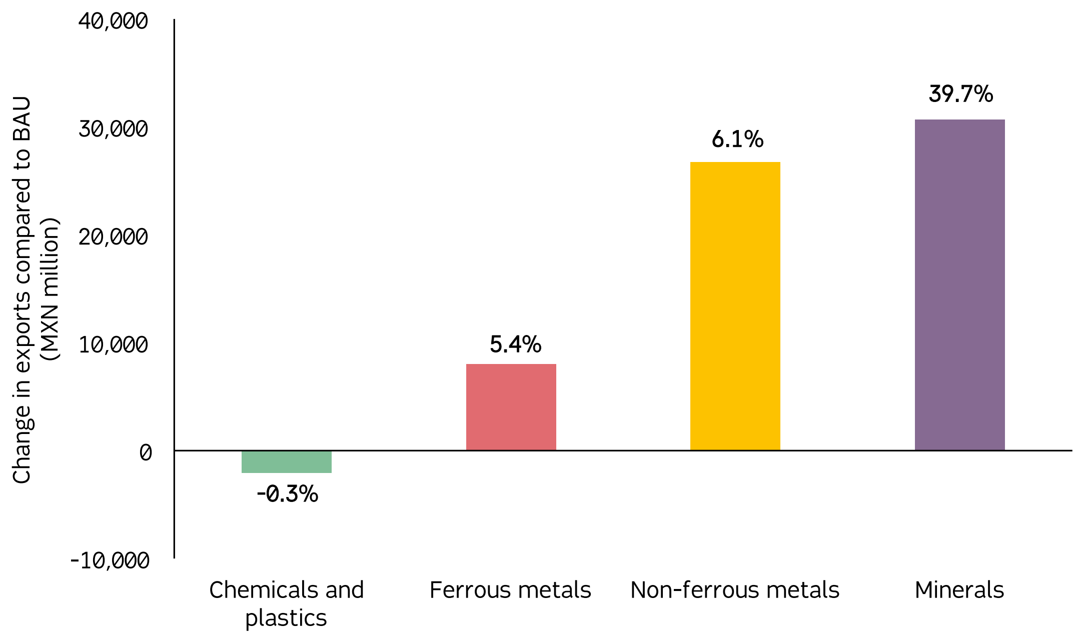
- **Ferrous metals:** exports increase 5.4%, though GVA impacts are smaller increasing 1.7% compared to BAU. This suggests ferrous metal production may benefit from higher climate policy costs in other regions and increased US import demand. As a result, the economy-wide analysis suggests ferrous metals are less at risk of carbon leakage than other sectors if most countries adhere to their NDC targets.

- **Non-ferrous metals:** exports increase 6.1% and sector GVA increases 4.2% compared to BAU. This suggests non-ferrous metals may also benefit from stricter climate policies in other regions and increased US import demand. As a result, the economy-wide analysis suggests that non-ferrous metals are less at risk of carbon leakage than other sectors if most countries adhere to their NDC targets.

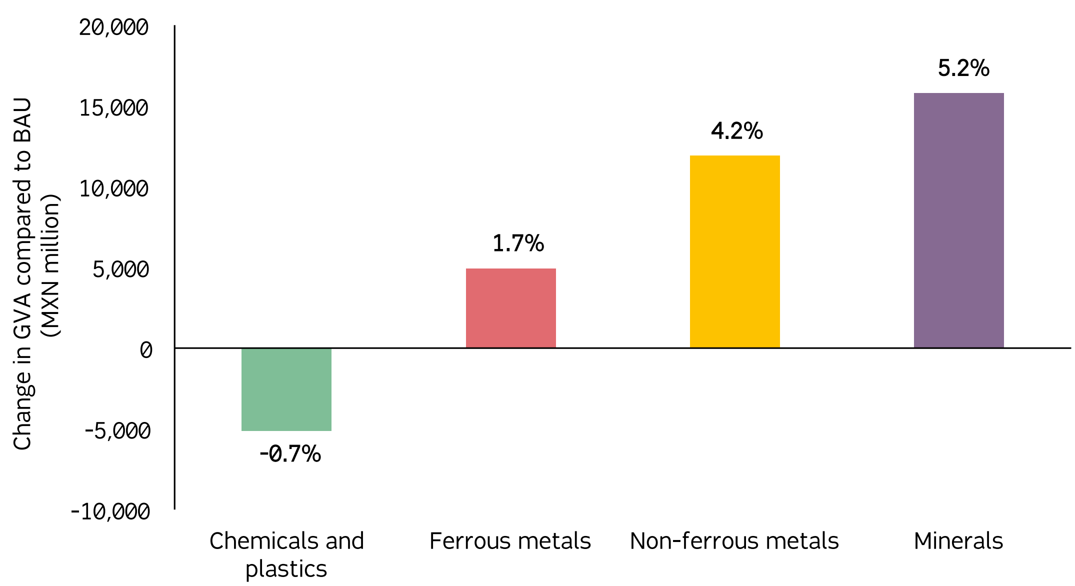
- **Chemicals and plastics:** exports decline by 0.3% while GVA declines by 0.7% compared to BAU. This implies that as the US and becomes more competitive, US chemical and plastic exports may displace exports from Mexico. The greater relative GVA decline suggests that US competition may also compress margins for the sector. Considering the decline in exports and GVA compared to BAU, chemicals and plastics could be at risk of carbon leakage.

Figure 5. Trade and GVA impacts by sector

Change in exports by sector



Change in GVA by sector



Source: Vivid Economics

3.2. Sectoral analysis

The sectoral analysis focuses on 6 key sub-sectors which *ex ante* may be at high risk of carbon leakage: iron and steel; lime; cement; glass; pulp and paper; chemical industry. These sub-sectors are chosen for 2 reasons:

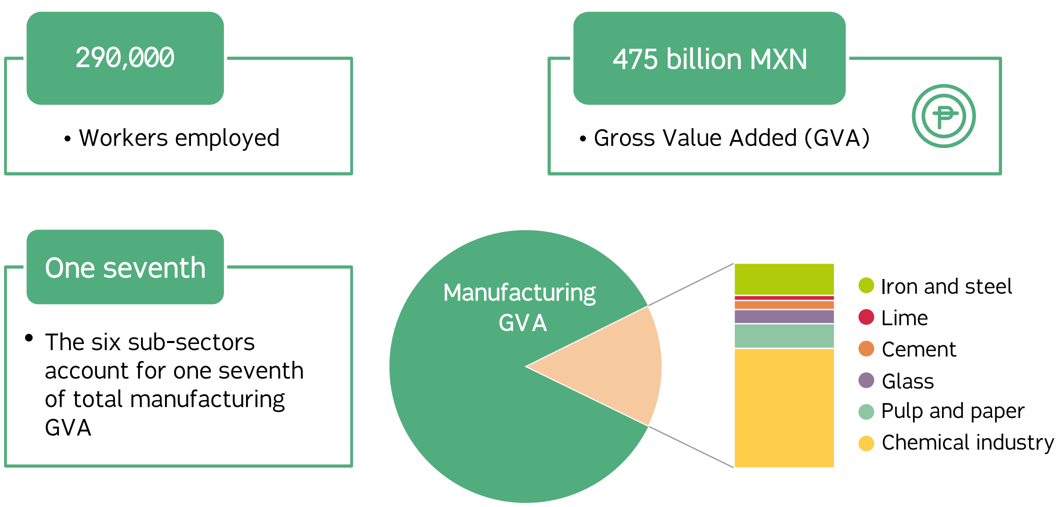
1. They are carbon intensive, and contribute significantly to Mexico's emissions. In 2014, they together emitted 86 $MtCO_2e$ in direct and indirect emissions, 18% of the country's total carbon emissions of 480 $MtCO_2$(World Bank 2018a), requiring them to play a significant role in Mexico's NDC to reduce emissions by 22% in 2030.
2. Most of the sub-sectors are trade exposed, and an important element of this trade is with countries without carbon pricing mechanisms. The sub-sectors exhibit trade intensity[(6)] up to 70%, making them highly exposed to international competition. The US, which does not price emissions at a federal level, is the biggest trading partner for all sub-sectors, ranging from 42% and 93% for imports and from 49% and 88% for exports.

Carbon leakage from these sub-sectors could have significant economic repercussions for Mexico: they represent a significant share of manufacturing gross value added (GVA) and employment:

- The six sub-sectors comprise 16% of Mexico's manufacturing value added (World Bank 2018b) with the chemical industry contributing the largest share (8% of the total).
- Upwards of 290,000 people are directly employed in the six sub-sectors in Mexico.
- The sub-sectors further provide essential inputs to other important sub-sectors in the economy, including the manufacture of more complex (higher value-added) products and the construction sector.

The economic relevance of the six sub-sectors is summarised in Figure 6.

Figure 6. The six sub-sectors account for a high level of employment and national income



Source: Vivid Economics based on INEGI – Economic Information Bank and World Bank data

(6) Trade intensity is calculated as (imports + exports)/(production + imports), representing the share of trade volume in domestic market size.

The remainder of this section is structured as follows:

– Section 3.2.1 describes the methodology for the sectoral analysis, introduces the three international metrics and explains the performed sensitivity tests.

– Section 3.2.2 summarises the results for the six-sectors.

3.2.1. Methodology

Policy makers have generally used two main metrics to estimate leakage risk: trade intensity and (carbon) cost increase. Trade intensity is intended to capture the capacity of a firm to pass through carbon costs to consumers without losing profit margins or market share to international competitors. The cost increase metric is intended to capture a sub-sector's direct and indirect cost exposure to a carbon pricing mechanism. Box 3 explains why these two metrics have been employed over other possible indicators.

Box 3. Theoretical indicators of carbon leakage risk may not be feasible for practical analysis

The academic literature identifies two main considerations for assessment of sectoral leakage risk:

1. Carbon cost impact: the impact that carbon pricing has on a particular firm or sector; and
2. Whether they have the capacity to pass through carbon costs to consumers without loss of market share or profit margin (carbon cost pass-through capacity).

However, each of these channels is difficult to observe in practice given data limitations and is therefore often estimated through use of a proxy:

– Carbon cost impact can be measured by volume of emissions created per unit of output, revenue, value added, profit. While this is often quite easy to capture, on some occasions emissions data may be challenging to gather. Proxies to capture carbon increase exposure include energy cost shares and, for indirect costs increases, electricity intensity.

– Measuring cost pass-through capacity is more challenging. A wide range of factors can be important including market power, elasticities of demand, the elasticity of domestic supply, elasticities of foreign supply. However, these are difficult to observe or measure and policymakers have tended to approximate through measurable drivers: most notably measures of trade intensity.

Carbon price differentials and abatement potential have not been used in practice to quantitatively measure carbon leakage risk, but are used in this analysis within the qualitative assessment:

– Abatement potential and cost can influence investment decisions and leakage. If a firm can reduce emissions at low cost it will be able to cost effectively reduce the carbon cost it faces, reducing the risk of leakage. However, this can vary significantly by firm;

– As carbon leakage is driven by carbon price differentials, if competing countries introduce carbon pricing policies of equivalent stringency, this should lessen the risk of leakage. However, prices can change quickly and so risk can similarly be highly variable.

This report employs 3 international methodologies which stand out as suitable for use in the Mexican context: California, EU ETS Phase III, and proposed EU ETS Phase IV. As Table 4 shows, all three of these methodologies use similar metrics of trade intensity and emissions intensity, facilitating calculation. Figure 7 illustrates graphically the three methodologies' different approaches to assessing leakage based on combinations of cost increase and trade intensity.

Table 4. The three methodologies have different criteria to determine sub-sectors at risk of carbon leakage

Scheme	Criteria	Definitions
California	Emissions intensity tiers are: High: >10,000 t CO_2e per million dollars of revenue; Medium: 1,000-9,999 tCO_2e per million dollars of revenue; Low: 100-999 tCO_2e per million dollars of revenue, very low: <100 tCO_2e per million dollars of revenue Trade intensity tiers are: High: >19%; Medium: 10-19%; Low: <10%	Emissions intensity calculated as tonnes of CO_2e per million dollars of revenue metric Trade intensity: (imports + exports)/(imports + production)
EU ETS Phase III	Cost increase >30%; or Trade intensity >30% or Cost increase >5% and trade intensity >10% Qualitative assessment for borderline sub-sectors	Cost increase: [(assumed carbon price × emissions) + (electricity consumption × carbon intensity of production × carbon price)]/GVA) Trade intensity: (imports + exports)/(imports + production)
EU ETS Phase IV	Carbon intensity × Trade intensity >0.2 Qualitative assessment for borderline sub-sectors	Trade intensity: (imports + exports)/(imports + production) Carbon intensity: kgCO_2/GVA

Source: Vivid Economics

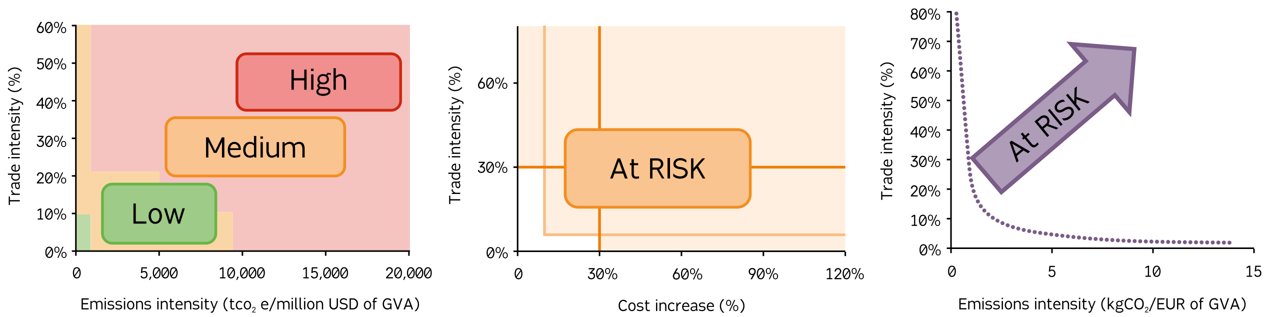
While the three metrics have particular features with advantages and disadvantages, taken together they offer a holistic picture of leakage risk.

- **California** uses trade intensity and emissions intensity but determines leakage risk in a tiered manner. This allows a more granular identification of risk rather than reducing it to a binary assessment as is done under both above phases of the EU ETS.

- **EU ETS Phase III** determines risk based on either high trade intensity or high cost increase, or both. While this method is easy to implement as it is based on readily available data, it fundamentally relies on an assumption of a carbon price. A sub-sector can further be identified purely based on one metric – trade intensity or carbon cost increase – meaning that it may not provide a particularly nuanced picture of leakage risk in a given sub-sector.

- **EU ETS Phase IV** multiplies trade intensity with an estimate of emissions intensity and compares this product against a threshold. While this removes the reliance on a carbon price assumption of Phase III, it still relies on the choice of an explicit threshold. This new method ensures a sub-sector's cost increase and trade intensity are considered together which is also attractive. At the same time, the methodology is still easy to implement.

Figure 7. The three international metrics take different approaches to the combination of trade intensity and emissions intensity into leakage risk



Source: Vivid Economics

Alternative methods present challenges. Firstly, New Zealand's methodology is contextually inappropriate for Mexico as its trade intensity metric relates to maritime trade. Secondly, South Africa is still in the process of reviewing its methodology and the current draft includes metrics which would be infeasible in Mexico due to data limitations. While it is in the process of implementing a nationwide carbon pricing instrument, China has not yet published its method for selecting sub-sectors at risk of leakage. Finally, South Korea uses the same metric as that used in the EU ETS Phase III, and so is already covered here.

The approach also performs three sensitivity checks to ensure results are robust to changes in key assumptions and variables:

1. **Carbon price assumption:** The formula used under the EU ETS Phase III is based on a EUR30 carbon price assumption. This price has not prevailed in the EU ETS yet and might not prevail in the Mexican ETS in the near future either. The sensitivity check finds the price threshold under which each sub-sector qualifies to be at risk.
2. **Exclusion of carbon-priced trade:** There is lower risk of carbon leakage to jurisdiction with a carbon pricing scheme in place. The sensitivity test investigates how the trade intensity metric changes with the exclusion of EU ETS countries, California and the 9 US states that are part of the Regional Greenhouse Gas Initiative (RGGI)[7].
3. **Exclusion of indirect emissions:** The role of indirect emissions depends on whether the power sector can pass through carbon costs, and this is likely to vary based on regulatory conditions and competitive dynamics at a local level. The sensitivity test analyses emissions intensity without indirect emissions.

Details on the methodology and step-by-step guidance on the calculation of the international carbon leakage risk metrics is provided in Appendix A.

3.2.2. Summary of sub-sector assessment

The analysis shows that all sub-sectors except lime are identified at risk under the three metrics. These five sub-sectors are clearly identified to be at risk under the EU ETS Phase III and Phase IV indicators and at high risk under the Californian metrics. Table 5 summarises the results for all six sub-sectors under the three selected metrics.

(7) States participating in RGGI are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont.

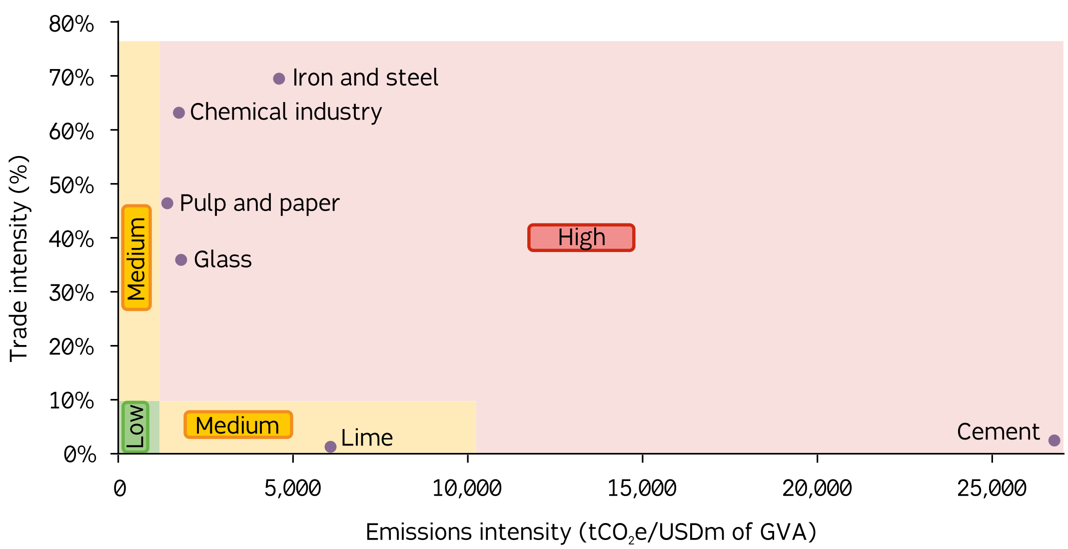
Table 5. Summary of carbon leakage assessment

Sub-sector	California			EU ETS Phase III				EU ETS Phase IV
	Trade Intensity Metric	Emissions Intensity Metric	Level of Risk	Trade Intensity Metric	Cost Increase Metric	Joint Metric	At Risk?	At risk?
Iron and Steel	High	Medium	High	Yes	No	Yes	Yes	Yes
Lime	Low	Medium	Medium	No	No	No	No	No
Cement	Low	High	High	Yes	No	Yes	Yes	Yes
Glass	High	Medium	High	Yes	No	Yes	Yes	Yes
Pulp and paper	High	Medium	High	Yes	No	Yes	Yes	Yes
Chemical industry	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Under California's three-tier indicator, iron and steel, cement, glass, pulp and paper, and the chemical industry are identified at high risk. Cement is identified due to high emissions intensity, the other four sectors due to a combination of high trade intensity and medium emissions intensity. Lime is identified as at medium risk as it exhibits low trade intensity and medium emissions intensity. While most other sub-sectors are clearly identified, pulp and paper is closest to the threshold of medium risk due to emissions intensity being close to low. Figure 8 depicts the six sub-sectors trade and emission intensity along the Californian thresholds.

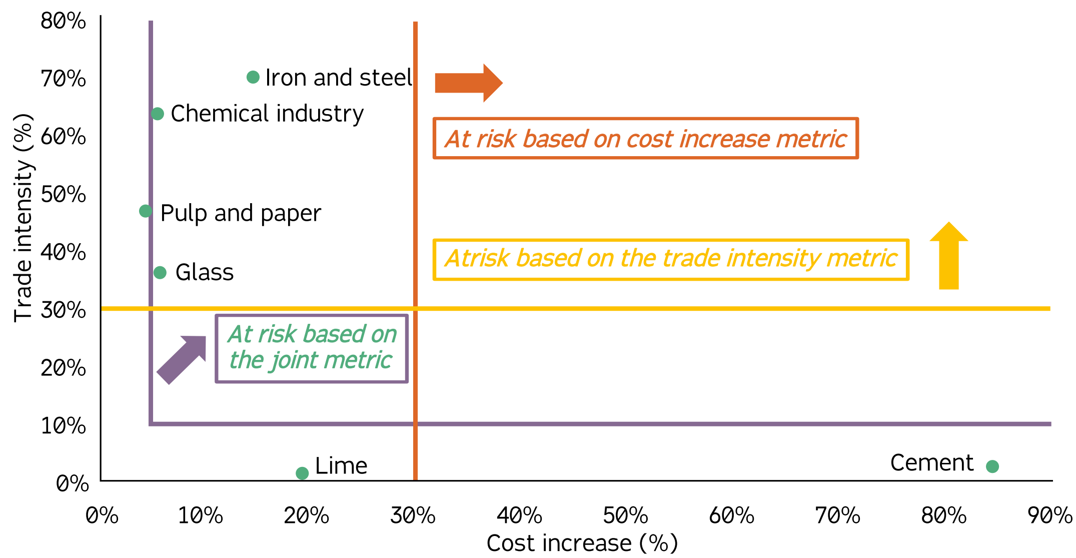
Figure 8. Carbon leakage assessment under the Californian metric



Source: Vivid Economics

The binary EU phase III metric identifies all sub-sectors except for lime as at risk, due to trade intensity, carbon cost increase or both. Glass, the chemical industry and iron and steel are identified under the trade intensity and the joint metric. Pulp and paper is only identified due to trade intensity and cement is only identified under the cost increase metric. Figure 9 displays the six sub-sectors according to the EU Phase III thresholds.

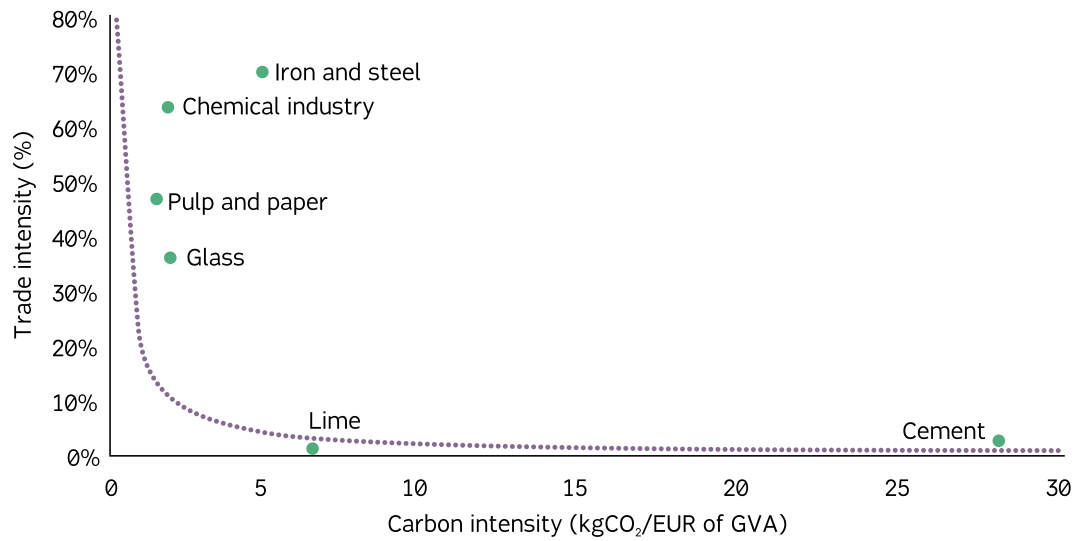
Figure 9. Carbon leakage assessment under the EU Phase III metric



Source: Vivid Economics

Under the EU Phase IV metric, all sub-sectors except lime are clearly identified to be at risk. Those five sub-sectors are clearly above the threshold constituted by the product of trade intensity and carbon intensity. In contrast, lime's combination of a medium carbon intensity and very low trade intensity results in the sub-sector being clearly not identified at risk, in line with the two other indicators. Figure 10 illustrates the six sub-sectors along the EU Phase IV threshold.

Figure 10. Carbon leakage assessment under the EU Phase IV metric



Source: Vivid Economics

The sensitivity test on the EU Phase III carbon price assumption suggests that cement is not identified under a carbon price of EUR10. For the sub-sector to be at risk under this metric, a carbon price of EUR10.82 (USD12.79) is required. While the carbon price in the EU ETS exceeded that threshold earlier this year and is currently around EUR15, it has been well below EUR10 for most of the time in Phase III. The original EU Phase III carbon price assumption of EUR30 has never prevailed in the EU ETS so far. Lime is never identified at a plausible carbon price. The other sub-sectors are always identified due to their high trade intensity. Table 6 summarises the results of this sensitivity test.

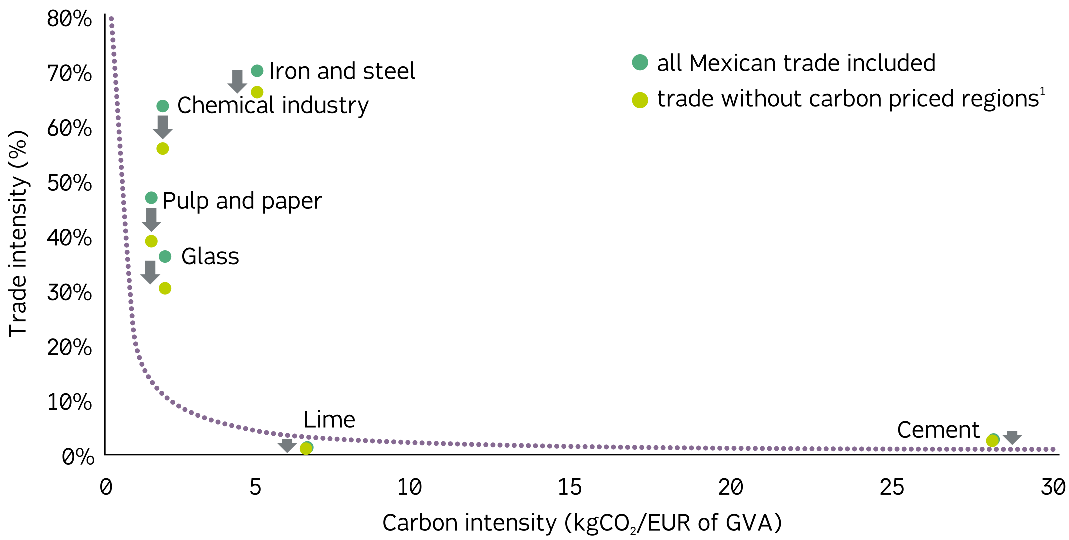
Table 6. Cement would only qualify above a certain carbon price in the EU ETS Phase III metric

Sub-sector	Necessary carbon price to be identified by cost increase or joint metric (EUR/tCO_2)	Always identified due to trade intensity?
Lime	**47.72**	**No**
Cement	**10.82**	**No**
Pulp and paper	36.24	Yes
Chemical industry	28.61	Yes
Glass	27.79	Yes
Iron and steel	10.57	Yes

Source: Vivid Economics

Excluding trade from carbon-priced regions does not change the identifications of sub-sectors. Some sub-sectors exhibit substantially reduced trade intensity, most notably the glass sub-sector, whose trade intensity is reduced by around one-sixth. However, all five previously identified sub-sectors remain above the trade threshold and/or are still identified due to their emissions intensity. Figure 11 illustrates the change in trade intensity along the EU Phase IV indicator, identification under the other indicators remains unchanged as well.

Figure 11. The exclusion of trade with carbon-priced regions does not change identification of sub-sectors

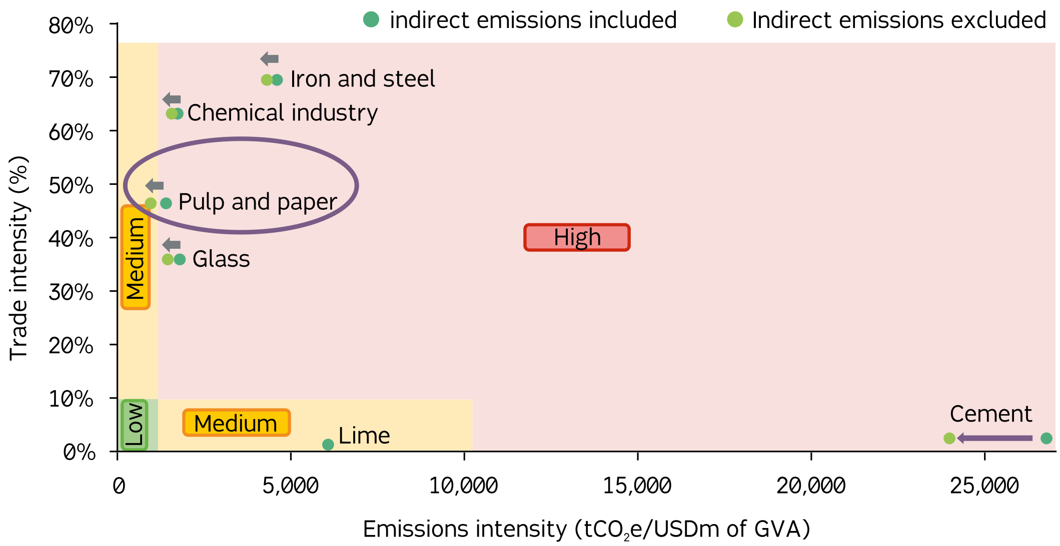


Note: Excluded are the EU ETS countries (EU members, Iceland, Norway), California, and RGGI states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, Vermont)

Source: Vivid Economics

Excluding indirect emissions changes the risk assessment of the pulp and paper sub-sector under the Californian metric to *medium*. The role of indirect emissions depends on the ability of the electricity sector to pass through carbon costs. If the ability is heavily constrained through market dynamics or regulations, the carbon price will also affect the industrial sector less, as indirect emissions are not fully priced for end users. Excluding indirect emissions in pulp and paper makes the sub-sector fall below the threshold of medium emissions intensity (1,000 tCO_2e/USDm), resulting in an overall identification of medium risk. For all other sub-sectors, the reduction in carbon cost exposure is not sufficient to change identification. Figure 12 displays the changes for all sub-sectors under the Californian metric.

Figure 12. Exclusion of indirect emissions reduces pulp and paper's level of risk to medium



Note: Sensitivity test not performed for lime due to lack of data availability
Source: Vivid Economics

The following subsections provide a high-level summary for each sub-sector.

3.2.2.1. Iron and steel

Analysis of the iron and steel sub-sector produced the following results:

1. California metric: iron and steel identified to exhibit 'high' leakage risk based on high trade intensity;
2. EU ETS Phase III metric: iron and steel identified based trade intensity;
3. EU ETS Phase IV metric: iron and steel identified.

Table 7. International metrics clearly identify the iron and steel sub-sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the iron and steel sub-sector as at risk. Changes in assumptions on carbon price, exclusion of trade with jurisdictions with carbon pricing in place, and indirect emissions do not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the low capacity rate and the high trade exposure, especially to jurisdictions without carbon pricing suggest that the sub-sector would not be able to substantially pass through carbon costs. This could aggravate carbon leakage risk.

– the high market concentration and tentative evidence from other jurisdictions suggest that cost pass-through capacity may be high. Furthermore, there are a range of abatement options available for the sub-sector which could reduce emissions intensity and therefore carbon costs. This could reduce carbon leakage risk.

3.2.2.2. Lime

Analysis of the lime sub-sector produced the following results[8]:

1. California metric: lime identified to exhibit 'medium' leakage risk based on medium emissions intensity;
2. EU ETS Phase III metric: lime not identified;
3. EU ETS Phase IV metric: lime not identified.

Table 8. International metrics do not identify the lime sub-sector to be at (high) risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	Trade intensity	Emissions intensity	Level of Risk	Trade intensity	Cost Increase	Joint Metric	Identified	Identified
Initial Assessment	Low	Medium	Medium	No	No	No	No	No

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the lime sub-sector as not at (high) risk. Sensitivity analysis of results to assumptions on carbon price and exclusion of trade with jurisdictions with carbon pricing in place does not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the substantially lower emissions intensity compared to other jurisdictions indicates that emissions might not have been reported comprehensively for the sub-sector. If actual emissions intensity is significantly higher, this would increase carbon leakage risk.

– the high market concentration and the marginal trade intensity suggest that cost pass-through capacity may be high. This could reduce carbon leakage risk.

(8) Emissions for the sub-sector are estimated due to lack of data. The sector brief in Appendix B describes the methodology in detail.

3.2.2.3. Cement

Analysis of the cement sub-sector produced the following results:

1. California metric: cement identified to exhibit 'high' leakage risk based on high emissions intensity;
2. EU ETS Phase III metric: cement identified based on the cost increase metric;
3. EU ETS Phase IV metric: cement identified.

Table 9. International metrics clearly identify the cement sub-sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	Low	High	High	No	Yes	No	Yes	Yes

Source: Vivid Economics

Cement's identification in the EU ETS Phase III metric is sensitive to the carbon price assumption. Only above an assumed carbon price of EUR10.82 (USD12.79) would the sub-sector be identified. Sensitivity analysis of results to assumptions on exclusion of trade from carbon-priced jurisdictions and indirect emissions does not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the low capacity rate and the high trade exposure, especially to jurisdictions without carbon pricing suggest that the sub-sector would not be able to substantially pass through carbon costs. It is reinforced by tentative evidence from other jurisdictions on carbon cost pass-through. This could aggravate carbon leakage risk.

– the high market concentration and low international competition suggest that cost pass-through capacity may be high. The higher emissions intensity compared to other jurisdictions and the availability of a range of abatement options available for the sub-sector suggests room for abatement. This could reduce carbon leakage risk.

3.2.2.4. Glass

Analysis of the glass sub-sector produced the following results:

1. California metric: glass identified to exhibit 'high' leakage risk based on high trade intensity;
2. EU ETS Phase III metric: glass identified based trade intensity;
3. EU ETS Phase IV metric: glass identified

Table 10. International metrics clearly identify the glass sub-sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the glass sector as at risk. Changes in assumptions on carbon price, exclusion of trade with jurisdictions with carbon pricing in place, and indirect emissions do not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the low emissions intensity compared to other jurisdictions indicates that abatement options have already been utilised, lowering the potential for additional abatement. Furthermore, most of the sub-sector's trade is with jurisdictions without carbon pricing. This could aggravate carbon leakage risk.

– the tentative evidence from other jurisdictions on carbon cost pass-through suggest that cost pass-through capacity may be high. The past growth and the recent investments suggest a dynamic sub-sector. This could reduce carbon leakage risk.

3.2.2.5. Pulp and paper

Analysis of the pulp and paper sub-sector produced the following results:

1. California metric: pulp and paper identified to exhibit 'high' leakage risk based on high trade intensity;
2. EU ETS Phase III metric: pulp and paper identified based trade intensity;
3. 3EU ETS Phase IV metric: pulp and paper identified.

Table 11. International clearly identify the pulp and paper sub-sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

The sensitivity analysis changes the assessment of the pulp and paper as at *high risk.* An exclusion of indirect emissions leaves the sector only at medium risk, suggesting that if cost pass-through in the power sector is low pulp and paper's carbon leakage risk is less severe. The other sensitivity tests do not alter the initial assessment.

There are several factors additionally affecting the carbon leakage risk:

- the high trade exposure, especially to jurisdictions without carbon pricing, suggest that cost pass-through may be limited. Additionally, the comparison of emissions intensity with other jurisdictions indicates that some abatement options have already been utilised, limiting the potential for future abatement. This could aggravate carbon leakage risk.
- Mexican firms increased capacity and investment to attempt the accommodation of rapid growth of demand in recent years. It indicates that competition is currently not fierce and there may be some potential for cost pass-through. This could reduce carbon leakage risk.

3.2.2.6. Chemical industry

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the chemical industry produced the following results:

4. California metric: chemical industry identified to exhibit 'high' leakage risk based on high trade intensity;
5. EU ETS Phase III metric: chemical industry identified based on trade intensity;
6. EU ETS Phase IV metric: chemical industry identified.

Table 12. International metrics clearly identify the chemical industry at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the chemical industry as at risk. Changes in assumptions on carbon price, exclusion of trade with jurisdictions with carbon pricing in place, and indirect emissions do not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the high trade exposure, especially to jurisdictions without carbon pricing suggest that the sector would not be able to substantially pass through carbon costs. This could aggravate carbon leakage risk.

– the high market concentration in the petrochemical sub-sector and tentative evidence from other jurisdictions suggest that cost pass-through capacity may be high. This could reduce carbon leakage risk.

– the large diversity in products and product processes hinders the carbon leakage assessment for the whole sub-sector. More granular data must be collected and analysed to conclude on carbon leakage in the chemical industry.

4

Management and Mitigation of Carbon Leakage Risk

4. Management and mitigation of carbon leakage risk

This section discusses the management and mitigation of carbon leakage risk theoretically and provides practical policy options for Mexico. It presents various mitigation options theoretically, supplemented by practical examples and lessons learned. At the end of the section, different policy options are compared along different criteria. It will allow Mexican policymakers to mitigate economic, political, social and environmental risks while pursuing comprehensive carbon pricing to fulfil the country's Paris commitments.

The allocation of free allowances is the most commonly used policy response to carbon leakage.

Each mitigation option addresses three questions to offer a holistic understanding of its interaction with other policy objectives:

1. **How does it protect against carbon leakage?** Policy should address leakage in exposed sub-sectors.
2. **Does it maintain incentives to abate?** Policy should not affect abatement incentives negatively.
3. **Is the policy efficient?** Policy should be politically viable, if not advantageous, and avoid administrative complexity.

4.1. Free allowances

The allocation of free allowances is the most commonly used policy response to carbon leakage. Policy makers have often refrained from requiring firms to purchase the full amount of permits through auctioning. Instead, a share or all of the allowances were distributed for free based on a firm's and/or sector's previous emissions.

Within an ETS, free allowance allocations are the most common policy mechanism to address leakage. They involve firms receiving a portion of their emissions allowances for free using any of three mechanisms: grandfathering, fixed sector benchmarking, and output-based allocation. In practice, some schemes blur the lines between these options or are hybrids. But in general, the versions are distinct between the following categories:

– If the free allocation varies with the firm's historic emissions;

– If the free allocation varies with a firm's current output level.

A summary of the differences between the allocation mechanisms is provided in Figure 13.

Figure 13. There are three key free allocation mechanisms

		Do allocations vary in proportion to a firm's output?	
		Yes: allocations update with the firm's own output on a regular basis	No: allocations are based on a firm's historic output with occasional updating
Do allocations vary in proportion to a firm's emissions intensity?	Yes: allocations are directly proportional to the firm's own emissions intensity	*Effectively an exemption*	Grandfathering
	No: allocations are benchmarked to independent measure of emissions intensity	Output-based allocation	Fixed sector benchmark allocation

Source: Vivid Economics

4.1.1. Grandfathering

Under a grandfathering scheme, firms receive free allocations proportional to their historic emissions. This volume does not usually vary with current or future output levels. Firms can then sell unutilised permits or purchase lacking permits depending on the relation between historic and current or future emissions. Prominent examples of systems using grandfathering include the first two phases of the EU ETS, the first phase of the South Korea ETS (for most sectors), and various Chinese ETS pilots.

Leakage protection

Grandfathering is ineffective in reducing carbon leakage risk in its pure form. As allocation does not depend on current levels of output, incentives are not affected at the margin. If the carbon price induces a firm to reduce its output, this would still happen under grandfathering. If this decrease in domestic output is taken up by a firm or plant in another jurisdiction, carbon leakage will still be prevalent.

Only if the assistance level is regularly updated and closure rules are in place, grandfathering can have an effect on carbon leakage. Rather than maintain fixed assistance levels, schemes tend to adjust allocation decisions periodically. Updating creates a link between current output – and therefore emissions – and future allocations. Firms will know that reduced output and emissions in one phase of the scheme is likely to result in less assistance in the next phase of the scheme. This creates an incentive for continued production and hence reduces the risk of carbon leakage. Adjustments are typically made every three years, such as in the early phases of the EU ETS. Schemes have additionally implemented a variety of closure rules. These rules make the allocation of allowances contingent on a minimum level of production, thus reducing the risk of carbon leakage beyond a certain threshold.

Abatement incentives

Grandfathering preserves the incentives to abate emissions, at least in the shortrun. Since a firm can always sell the free allowances, the marginal costs of emitting carbon are the same as if all permits are auctioned. However, it has distributional impacts as firms do not have to pay for all their emissions and consumers and the government have less or no revenue. Therefore, it has often been used to win political support at the stage of implementation and then reduced in favour of auctioning at a more mature stage.

Grandfathering may also drive demand-side abatement if domestic Mexican product prices increase. In a sector with limited import competition, such as Mexican cement or lime, a reduction in output brought about by carbon price increases would result in a rise in domestic product prices. This may lead to some demand-side abatement, such as consumer substituting to less emissions-intensive alternatives.

However, grandfathering jeopardises the long run efficiency and can create perverse incentives. Through free allowances, inefficient firms might be kept in the market. In addition, free allowances can be used by incumbents to prevent market entry. Moreover, firms face an incentive to not reduce output and emissions as future free allowances depend on current production.

Policy efficiency

Grandfathering exhibits relatively low administrative burden due to its ease of implementation. Historic emissions are the only data requirement to calculate the level of assistance, far less than for product- or sector-specific benchmarks.

The mechanism can be appealing to generate industry stakeholder buy-in and general political support for carbon pricing. It has been used broadly in the past by other jurisdiction to win over support in the beginning of an ETS and/or to provide on-off assistance to firms in the transitional period. In more mature carbon markets, policymakers are gradually moving away from grandfathering.

However, grandfathering can also be politically challenging if windfall profits are generated. This can occur if the mechanism is applied to sectors not exposed to carbon leakage. If firms have the ability to pass through the costs of carbon to consumers and at the same time receive free allowances this can produce these windfall profits. A popular example are power generators in the EU ETS. Through the design of the European electricity market, electricity producers face little trade exposure and were able to profit from this allowance design(Hintermann, Peterson, and Rickels 2015).

Implications

Grandfathering presents an attractive option for Mexico during the pilot phase of its ETS mechanism but is unlikely to address leakage risk beyond the short term. Grandfathering does not effectively address output and carbon leakage in exposed sectors and is rarely adopted as a long-term carbon leakage mitigation option. Furthermore, improving its effectiveness at reducing leakage by implementing updating or closure rules compromises abatement incentives, as firms would then expect future assistance levels to be based on current emissions. However, there may be a strong political role for the grandfathering approach as a form of transitional assistance in Mexico, ensuring sector stakeholder buy-in during the initial phase.

4.1.2. Fixed-sector benchmark allocation

In fixed-sector benchmarking (FSB), the number of free allowances a firm receives is proportional to an emissions intensity benchmark of its respective sector or product. In contrast to grandfathering, the allocation does not depend on the firm's historic emissions. Assistance levels are determined with reference to product or sector-level benchmarks. Similarly to grandfathering, the allocation does not vary with current output levels. Box 4 discusses the mechanism applied under the EU ETS Phase III.

Box 4. Fixed sector benchmarking under EU ETS Phase III

The fixed sector benchmarking allocation approach under EU ETS Phase III uses product-related emissions benchmarks to determine the free allocations of each installation. These benchmarks are set using the emissions levels of each sector's 10% most efficient installations. This system is designed to reward highly efficient installations and incentivise emissions reductions of less-efficient installations. While the benchmark factors in historic production, the amount of free allocations received by an installation does not change over the period of Phase III.

In other words, this approach has a very long period in which the output basis of the allocation is not updated. In the absence of other measures, this would tend to weaken its effectiveness in preventing leakage. To help address this challenge, adjustments have been made to create a stronger link between allocations and output, subject to some minimum threshold of output, which therefore facilitates stronger protection against leakage. For example, firms producing more than 50% of their historic level receive their full free allocation, including if their output exceeds their historic activity level.

However, the risk of gaming remains. By setting production at a level just above a threshold, firms can receive allocations that exceed the carbon emission costs they face. For example, at an output level of 51% of their historic activity level, firms would be entitled to receive 100% of their allocation (Branger et al. 2014).

The change of allocation rules from Phases I and II to Phase III reduced the scope for windfall profits while also mitigating leakage risk. Benchmarking further improves the harmonisation of free allocation levels between countries relative to Phase II. However, it does not remove the possibility of windfall profits and other internal market distortions, as benchmarks are calculated according to ex ante output levels.

Leakage prevention

The effectiveness of fixed sector benchmarking in addressing leakage depends on closure rules and updating benchmarks. If a fixed sector benchmarking scheme does not alter the level of assistance time, it results in a similar dynamic as under grandfathering – namely that sectors exposed to international competition from jurisdiction without a carbon price would still reduce production and lose market share to competitors. Accordingly, policymakers using fixed sector benchmarking are likely to supplement it with closure rules and periodic updating to reduce the risk of leakage.

Abatement incentives

The incentive to reduce emissions under FSB is stronger than under grandfathering. Since the number of free allowances depends on the performance of the industry, a single firm's output has little impact on its future allowance. The link between a firm's individual emissions intensity and the allowance level is aggravated.

The stringency of the benchmark has only a minimal effect on the incentives to reduce emissions. The marginal costs of emitting are still defined by the permit price. From an economic perspective, the benchmark has only distributional effects. A stricter benchmark increases expenditures of firms on permits and revenue available for the government and consumers, and vice versa. Policy makers usually set benchmarks somewhere between the average and the most efficient firms in a sector. From a behavioural perspective however, firms might respond stronger to additional costs of buying permits above the benchmark than further reducing emissions below the benchmark.

Policy efficiency

FSB requires comprehensive data and should include updating as well. Sub-sectoral benchmarks are less data-intensive but might not appropriately assess carbon leakage risks. If benchmarks are designed by product, complex supply chains and different production processes can make an assessment complicated. However, the successful use of benchmarks under fixed sector benchmarking in the EU, and output-based allocation mechanisms in New Zealand, the former Australian scheme and California indicate that these technical challenges can be overcome.

Similarly to grandfathering, FSB could deliver windfall gains if applied to sectors that are not exposed to leakage. As the level of allocation is independent of current output levels, firms that compete only domestically will have an incentive to respond to a carbon cost by reducing output and raising prices. As under grandfathering, this increase in prices could stimulate some demand-side abatement but may also lead to windfall profits. While such windfall profits may smooth the transition to an ETS, they could simultaneously result in concerns and criticism from the public.

Implications

In summary, FSB could be used after the pilot phase of the Mexican ETS to support sectors at medium risk of carbon leakage. Abatement incentives are better preserved than under grandfathering. However, without the implementation of closure rules and updating, fixed sector benchmarking will still face the same challenges in terms of leakage prevention, and windfall profits and reduced production are still possible. For sectors at high risk of carbon leakage, FSB might not provide sufficient carbon leakage risk prevention.

4.1.3. Output-based allocations

In an output-based allocation (OBA) mechanism, the amount of assistance varies with a firm's output, relative to a sectoral emission intensity level. The initial allocation of permits can be equal or similar to a FSB approach. However, if a firm changes its current output, the number of allowances are adjusted as well. This means that when firms increase or decrease their output, the amount of allowances they receive rises or falls correspondingly, according to the pre-defined emissions intensity benchmark. Variants on this basic model are used to provide assistance in California, per Box 5, and New Zealand. Phase IV of the EU ETS moves slightly closer to this system also.

Box 5. Californian output-based allocation

The California ETS uses a form of output-based allocation to reward efficiency and deter gaming. Facilities that are more efficient than their competitors are rewarded using benchmarking, and the system ensures that an entity cannot increase its allocation by artificially increasing or decreasing production at strategic times (EDF, CDC Climate, and IETA 2015).

To determine the amount of free allowances distributed to industry, the California Air Resources Board (ARB) created the industry assistance factor. Assistance is provided on the basis of three leakage classifications:

- High risk, which includes oil and gas extraction, paper mills, and chemical, cement, iron, steel, lime manufacturing;
- Medium risk, which includes petroleum refineries and food and beverage manufacturing; and
- Low risk, which includes pharmaceutical and aircraft manufacturing.

California is moving away from free allocation based on this leakage risk determination. For the first and second compliance periods (2013–14 and 2015–17, respectively), approximately 90% of industrial allowances were freely allocated, regardless of leakage classification. However, for the third compliance period, entities in the medium and low categories are freely allocated 75% and 50% of their allowances, respectively.

Allocation is calculated through a combination of industry and firm-level data. For the operator of an industrial facility, allowance allocations are determined by multiplying total product output or energy consumed by an emissions benchmark, an industry assistance factor and cap adjustment factor (a fraction that decreases to reflect a tightening emissions cap). While product output or energy consumed is calculated at the facility level, the remaining variables are determined at the sector level.

Leakage prevention

OBA addresses carbon leakage more vigorously than FBS or grandfathering. This is due to the strong link between emissions and allowances. In contrast to FSB or grandfathering, this approach actually affects the production decision on the margin. When a firm produces an extra unit of output, this will directly result in allocation of additional allowances. The volume preservation feature could be even more attractive if firms pursue abatement that reduces their carbon intensity only if they are confident that high levels of output are likely to be maintained in the future, as is likely to be the case in Mexico given positive economic projections.

The value of the benchmark could have significant impacts on the level of leakage. Due to the direct link between firm production and allowances received, the value of the benchmark is likely to have material effects on production incentives:

- A more stringent benchmark would offer weaker protection of Mexican sectors against leakage as most firms would have lower emissions intensities and experience net production cost increases for additional units of output.

- Conversely, if the benchmark is higher it could have the perverse outcome that even firms with relatively high emissions intensity that is still below the benchmark increase production.

In practice, output-based allocation approaches have tended towards the use of benchmarks that are between the average and best practice of emissions intensity of the industry in the relevant jurisdiction. Benchmarks also often change over time to reflect the tighter emissions targets or expected firm efficiency improvements.

Abatement incentives

OBA benchmarks preserve abatement incentives. By using benchmarks, output-based allocation provides less carbon-intensive firms with a competitive advantage through lower-carbon emission costs net of allocations. Similarly to fixed sector benchmarking, this property broadly preserves the desired nature of competition that gives emissions-efficient firms an advantage over less emissions-efficient firms. All else being equal, the efficiency-preserving properties of the two benchmarking approaches, output-based allocation and fixed sector benchmarking, make them preferable to grandfathering because of abatement incentives.

One downside of OBA is that the environmental outcome becomes uncertain, but this can be addressed by appropriate design. Usually, the total level of emissions in an ETS is fixed by the number of permits. However, if firms unlimitedly get more allowances proportional to their output, this might exceed the overall cap. To mitigate this risk, benchmarks can be reduced over time and/or a cap on OBAs could be set, even though this weakens the protection from carbon leakage. Another option is to reduce the number of permits auctioned according to the allowances distributed through OBA. Under this approach, the careful selection of sectors at risk are even more important, as it has a greater effect on firms and since it determines the leeway the free allowances can widen. Stringent benchmarks and regular updates can help guaranteeing environmental integrity (Zipperer, Sato, and Neuho 2017).

OBA could incentivise higher production and thereby limit price increases in the affected sectors, which would dull demand-side abatement. The approach may provide strong incentives for firms to maintain or increase production levels as allowances are dependent on current output, and higher output will increase allowances received, all else being equal. In turn, higher levels of output could result in lower end-user prices compared with alternative allocation mechanisms. While this is valuable in protecting against leakage in internationally exposed sectors, in sectors that are less exposed to international competition it may decrease demand-side abatement incentives. If there are insufficient incentives to implement demand-side abatement, there could be negative repercussions for the costs of reaching a given emissions reduction target.

Policy efficiency

Similarly to FSB, determining the value of the benchmark may be administratively challenging. The stringency of the benchmark will impact the degree of leakage protection: the more stringent the benchmark, the lower the level of protection for firms. However, if less stringent benchmarks are set, this could result in firms with relatively high emissions intensity increasing their production. The calculation of benchmarks for OBA will face similar complications as FSB, including the existence of different production processes for the same products or multi-product processes. These complexities could lead to significant lobbying for less stringent benchmarks from industry stakeholders.

Output-based allocation could protect against windfall profits in non-exposed sectors and the associated political challenges. Output-based allocation could result in price increases below those expected under other free allowance mechanisms. This suppression of price increases will in turn reduce the risk of windfall profits under an output-based allocation relative to grandfathering and fixed sector benchmarking. As windfall profits could undermine public confidence in the scheme, protection against them could serve as an important argument in favour of OBA.

Implications

Altogether, output-based allocations can be an effective approach to mitigate carbon leakage for high-risk sectors if carefully designed. They tackle leakage more effectively than grandfathering or FSB and are therefore especially attractive to sectors at high risk. Another benefit of OBAs for Mexico is that California uses this mechanism; using the same approach would facilitate linking of the two carbon markets. However, a careful design is necessary to ensure the environmental integrity of the Mexican ETS. Furthermore, the administrative burden of appropriate benchmarks are significant and are unlikely to be feasible at an early stage of the scheme.

4.2. Complementary measures

Complementary options are measures to mitigate carbon leakage separate from the ETS. These options compensate industry for the impacts of the carbon price – such as rebates, subsidies and other transfers including direct financial supports – or entirely protect the industry from the effects of the carbon price – such as an exemption.

4.2.1. Rebates

Policymakers may attempt to reduce leakage risk by providing industry with tax rebates or by providing subsidies – in other words, through transfers. This approach aims to support abatement while otherwise compensating industry for the associated increases in carbon costs. Often, such transfers are funded by recycling proceeds from the carbon pricing mechanism. Box 6 shows that under the EU ETS state aid compensation scheme, producers in electro-intensive industries may be entitled to transfers to compensate for the indirect cost increases they face due to the ETS.

Box 6. Application of EU state aid compensation scheme for indirect costs in the UK

The UK provided state aid compensation for indirect carbon costs under the EU ETS to avoid carbon leakage. Since 2013, the government has compensated eligible electro-intensive producers for increases in electricity costs and the risk of a loss of international competitiveness due to the ETS and its national Carbon Price Support. The UK applies maximum compensation levels allowed by the European Commission: 80% of eligible costs in 2017 and 2018; and 75% in 2019 and 2020, up to a limit. Should aid near the limit of the allocated budget, the government may choose to reduce aid intensity. It intends to continue compensation until 2020.

The compensation scheme was slow to be implemented and so provided little support, but nevertheless low carbon prices meant that the ETS's impact, and thus leakage risk, was small. The aid package was introduced by the government in 2011 and was due to be implemented in 2013, but most of the package was not implemented until 2016. However, low carbon prices nevertheless meant that the overall impact on electricity prices was small. The ETS and Carbon Price Support roles in the decline of cement, steel and aluminium in the UK has been negative but small (Cambridge Econometrics 2017).

Leakage prevention

To prevent or alleviate carbon leakage, the amount of rebate must change with the level of production. If the rebate is a lump-sum transfer, it will not have an effect on carbon leakage. It will only have a distributional impact as the government and/or the consumers would have less of the revenue, similarly to grandfathering. If revenue recycling is however linked to current or future output, it will provide incentives to mitigate carbon leakage. Similarly to OBA, sectors eligible for rebates should be carefully chosen to maintain incentives for demand-side abatement. Another approach is to tie rebates to outcomes linked to production, such as employment and its social security contributions. This approach represents a middle ground between lump-sum transfers and links to production, since connections to output are prevalent but less direct.

Abatement incentives

Rebates, and transfers in general, preserve incentives to reduce emissions intensities provided that they are not disbursed in proportion to emissions. Transfers are unlikely to distort the impact of the carbon price on firm abatement incentives: if emissions reductions are attractive to firms at the current and/or expected future carbon prices, the firm will be able to decrease its carbon price liability while the revenue it receives from transfers is unchanged. However, if the amount of rebate is relative to the emissions level, abatement incentives may be distorted.

Policy efficiency

Stakeholder buy-in could be facilitated during the transition towards a Mexican ETS through well-designed rebates or other transfers. These temporary measures could generally help to win over political support for the Mexican support. Administrative costs are usually low relative to benchmarks but depend on the respective design of the transfer.

Implications

Transfers, such as rebates, could support Mexico's broader objectives when implementing its ETS and could address carbon leakage risk if linked to output decisions. Most jurisdictions with carbon prices also have some combination of support for emerging renewable technologies, energy efficiency measures and support for low-emissions R&D. The nature and ambition of these policies varies across jurisdictions, but their broad adoption indicates the widespread acceptance of their value as part of the policy landscape to promote. The objective of these policies is often not directly related to carbon leakage risk, although there are a few cases where such measures have focused on leakage concerns. This requires a link to firms' output decision, otherwise transfers will not be effective in preventing leakage.

4.2.2. Exemptions

Most jurisdictions define their carbon pricing scheme in way that partly or completely excludes certain sectors or emitters. Exemptions could be driven by broader political concerns over exposing certain sectors to additional costs or practical difficulties, but also to address carbon leakage specifically. Small emitters are often found to be excluded due to high administrative costs. Generally often excluded are transport emissions, land use, land use change and forestry emissions, waste or agriculture emissions.

Leakage prevention

Exemptions can directly address carbon leakage by lowering the effective carbon price in targeted sectors. It reduces the exempted firms' carbon cost exposure significantly or completely. The sector would not have any disadvantages stemming from asymmetric carbon pricing, neither at domestic nor international competitions.

However, exemptions are likely to increase leakage risk in other sectors. For a given domestic emissions target, exempting a sector increases leakage risk in sectors covered by the ETS as ambition in these sectors must increase. Thus, these sectors would face extra leakage risk unless there are further prevention measures applied. Depending on the resulting carbon leakage risk in those other sectors, leakage could even increase in total.

Abatement incentives

Exemptions fundamentally undermine the effects of an ETS on abatement incentives, far more than any other discussed mitigation measures. Firms will have fewer incentives to reduce their emissions intensity. Moreover, carbon-intensive firms will not have a disadvantage over low-carbon firms and the latter may not gain market share over time. In addition, the absence of a carbon price will also not induce demand-side abatement.

Policy efficiency

Exemptions have little administrative burden and could cushion economic, social and political effects in key industries. Exemptions do not require sophisticated data and are easy to administer. They could help to win over political support on carbon pricing in other sectors in the economy in the phase-in of the ETS.

If exemptions are introduced they should be precisely targeted and have a clear plan to phase them out over time. Historically, carbon pricing indicatives have started with some excluded sectors to reduce political resistance and smooth the transition. As they undermine the initial objectives such as emissions reduction and the internalisation of externalities they should be phased out in the medium term. If exemptions remain active in the long term the affected sectors are unlikely to reduce their emission intensity and might fall behind international competitors. If carbon policies persist to be asymmetric in the long term, alternative carbon leakage measures might be necessary to replace the exemptions.

Implications

Exemptions jeopardise abatement incentives and the impact on total carbon leakage is ambiguous, but they are easy to implement. As exempted sectors would not face a (full) carbon price, their leakage risk would be significantly reduced. However, abatement in covered sectors would need to increase for a given national target, increasing leakage risk in these other sectors. Furthermore, exempted sectors face little incentives to reduce emissions intensity. Exemptions exhibit a low administrative burden and can win over political support during the ETS phase-in.

4.3. International mechanisms

International mechanisms, while they may be integrated in the Mexican ETS, are fundamentally dependent on external carbon pricing mechanisms and their relative stringency. This section analyses two such international mechanisms:

– Border Carbon Adjustments are price adjustments applied to traded goods designed to reduce the risk of carbon leakage.

– Linking, relies on a more collaborative approach and establishes a connection between different jurisdictions' carbon pricing regimes, for example with the Californian ETS to reduce leakage between the parties involved.

4.3.1. Border carbon adjustments

In the absence of global carbon pricing, Border Carbon Adjustments (BCAs) are a first-best solution for leakage prevention as they maintain abatement incentives while also protecting firm competitiveness. If integrated into an ETS, a BCA can reduce leakage risk by ensuring that domestic producers do not face an asymmetric carbon cost either domestically or externally, while also maintaining incentives for domestic abatement. Indeed, a Border Carbon Adjustment is a superior form of leakage risk prevention compared with free allocation of allowances as it directly addresses the difference in marginal costs that carbon pricing creates, implying no loss in competitiveness for domestic producers.

There are three possible forms of a Border Carbon Adjustment; in each case the objective is to reduce the risk of any competitiveness impacts of carbon pricing. The three forms are (Helm et al, 2012):

1. Border taxes (as tax adjustments on traded goods), where external firms must pay a charge, akin to a tariff, at the border which is equivalent to the carbon costs faced by domestic firms.
2. In cases of an ETS, mandatory emissions allowance purchases by importers, where external firms are required to purchase allowances at the border to sell into the domestic market.
3. Embedded carbon product standards, where external firms must meet certain standards with regard to the emissions intensity of their products in order to be able to sell into the domestic market.

Leakage prevention

BCAs are found to be effective in reducing carbon leakage. To date, border adjustments have barely been introduced, so empirical evidence is rare. However, it has been extensively studied in the theoretical literature and by ex-ante modelling. Branger and Quirion (2013) conducted a meta study on 25 previous investigations. Across all models and variations they find that BCAs reduce carbon leakage on average by 6 percentage points. This is a substantial amount considering that carbon leakage rates were only between 5 and 25 percent in the absence of a policy response. Analysis by Böhringer, Balistreri, & Rutherford (2012) suggests Border Carbon Adjustments on average reduced leakage rates from 12% to 8% relative to a no Border Carbon Adjustment or allocations reference scenario.

Abatement incentives

BCAs can mimic the economic and environmental benefits of a widely harmonised carbon pricing regime. Firms, domestic and foreign, would compete on a level playing field and not on the stringency of environmental regulation. All firms have an incentive to reduce emissions intensity and furthermore demand-side abatement is promoted. In addition, BCAs might encourage carbon pricing initiatives in other jurisdictions. By introducing its own carbon pricing scheme, a country would collect revenues domestically and would not change the competitive situation of its firms.

Some commentators raised the concern that leakage would be 'downstreamed' through BCAs but this is not expected to be significant in most cases. Since the sectors most at risk of carbon leakage involve energy-intensive transformation processes at the beginning of many supply chains, such as smelting and refining, downstream users might be affected by the BCA through higher input prices. As their international competitors might not face any carbon pricing scheme, leakage might move downstream. A consequence would be that more sectors need to be included and selection mechanisms need more information and effort to determine the BCAs. Nevertheless, since most downstream production processes have a higher value and are more elaborated, the embedded carbon content is lower than in upstream production.

Policy efficiency

The administrative burden associated with the related legislation may be substantial. Rules and definitions for how to calculate the emissions embodied are required, and especially the complexity of some products and their supply chains pose significant challenges (Kortum and Weisbach 2017). Rates could be based on facility, firm, or country, or conversely a product-level rate, all of which have different advantages and disadvantages. One possible solution is to include only sectors with relatively homogeneous products and simple supply chains to avoid these pitfalls (Helm, Hepburn, and Ruta 2012).

There are some legal constraints through the World Trade Organisation (WTO), but it expected that BCAs can be designed around them. The WTO's agreements set a framework under which new tariffs can be established which would be relevant for BCAs. They however allow for trade restrictions which protect human life or natural resources. A BCA would therefore merely need to demonstrate that it reduces emissions (Trachtman 2016). This could potentially challenge the variant with export rebates.

Political challenges might hamper the introduction of BCAs as experienced in the past. A popular example is the case when the EU planned to mandate flights from and into the European Economic Area to surrender allowances under the EU ETS in 2012. Developed and emerging countries responded by threatening countermeasures in case the legislation moved ahead such as charging European airlines. The EU suspended the proposal and to date non-domestic flights have not been included in the ETS. For Mexico, raising additional tariffs on US imports might be especially challenging. Border adjustments might become more feasible once a larger share of jurisdictions have introduced carbon pricing regimes and the threat of countermeasures become less serious.

Implications

In summary, border adjustments can ensure both environmental objectives and leakage mitigation but the implementation might be politically and administratively challenging. They incentivise both domestic and foreign firms to reduce emissions intensity while avoiding emissions to be shifted to other jurisdictions. Furthermore, they extend the reach of the carbon pricing regime beyond the domestic country's border. Nevertheless, the administrative effort to decide on the detailed design and the political resistance from other jurisdictions pose serious challenges to BCAs.

4.3.2. Linking

Linking establishes a collaborative connection between distinct carbon markets and may be direct or indirect, depending on the nature of the flow of allowances. Direct links create a one-to-one connection between two or more carbon pricing systems, such as in the ETSs of California, Quebec and Ontario, where allowances flow freely between systems. Indirect links rely on a common unit that can be exchanged between systems. The offset mechanism via the Clean Development Mechanism (CDM) used in some national carbon pricing systems is the primary example.

As California is a main trading partner, linking Mexico's ETS to the Californian ETS appears an attractive option. California accounts for more than one eighth of Mexico's trade with the US and has already a relatively mature carbon market. The Regional Greenhouse Gas Initiative (RGGI) could be an additional option to link Mexico's ETS to part of its trading partners.While in principle Mexico could also consider linkage with other countries, the effect on carbon leakage would be lower as their trade significance is lower. In general, the choice of partner will determine whether and how the link has an impact. An ETS design similar to potential partners would facilitate linking at a later stage(9).This section focuses on the effects of a potential link with California as it is currently the most viable option.

Leakage prevention

Linkage can help address concerns about distortions in a cooperative way, rather than implementing Border Carbon Adjustments, but would be geographically limited. Linking broadens flexibility in terms of where emissions reductions can occur, allowing participants to take advantage of a wider array of abatement opportunities, and increasing the cost-effectiveness of meeting emissions targets. It can also improve market liquidity and political commitment, and help address leakage and competitiveness concerns as well as facilitate international cooperation on climate policy.

However, linking with California could result in higher allowance prices in Mexico, increasing the risk of carbon leakage to other trading partners and necessitating further prevention measures. Linking only reduces the risk of carbon leakage between the linked jurisdictions, and for example not to other US states. Therefore, it requires further risk prevention measures for unlinked jurisdictions. Indeed, without further measures, a link with the Californian ETS could increase leakage risk: the link is likely to increase demand for Mexican allowances, which would consequently increase in price and lead to greater leakage risk to third countries.

Abatement incentives

Linking with the Californian ETS could lead to more abatement in Mexico. Linking expands the overall ETS market and enhances cost-effective functioning by increasing market liquidity and diversity in marginal abatement cost. Linking can offer access to more low-cost emissions reductions for Californian producers. Given that carbon prices in Mexico would be likely to increase due to rising demand for Mexican allowances, it is likely that higher cost abatement opportunities in Mexico would be achieved. If emissions reduction costs are lower in one system, linking can shift emissions reductions there.

Policy efficiency

Linking with the Californian ETS would lead to significant financial flows into Mexico. It is likely that linking with the Californian ETS would lead to financial flows into Mexico as Mexican producers minimise compliance costs. Similar results have been obtained using models of financing flows in the international carbon market.

Linking could increase carbon market liquidity and depth, and the climate policy commitment would lead to greater policy stability. A larger, more diversified carbon market in Mexico would provide a stronger and more stable carbon price signal and reduce the potential for market manipulation. Deeper markets incentivise climate-smart investment and facilitate the sale of sophisticated risk management instruments such as derivatives.

(9) California has four statutory requirements for ETS linking: the requirements for offsets in the linked ETS to be stricter or equivalent to the Californian; the Californian government to remain able to enforce emissions compliance obligations against entities inside or outside of its jurisdiction; equivalent or stricter enforcement of program requirements and applicable laws after linking; and no legal liability for the state and its entities in case of any failure associated with the link(PMR 2014).

However, significant administrative and political challenges have presented key barriers to ETS linking internationally. Negotiations to determine the detailed mechanisms of the link can be lengthy, technical and administratively complex. They will fundamentally depend on the similarity of the initial ETS designs. If Mexico intends to link with the Californian ETS in the future, it could reduce the administrative cost of a link pre-emptively by aligning its ETS with the Californian from the outset.

Implications

While linking with the Californian ETS may be attractive in the long term due to potential capital inflows, it is infeasible in the short term and would necessitate further leakage risk prevention policymaking. The option is attractive from the point of view of increasing regional cooperation on abatement and higher financial flows into Mexico from California, and can result in higher cost abatement opportunities in Mexico being achieved. However, given the expected rise in Mexican carbon prices as a result of the link, leakage risk to third countries would likely increase in the absence of further leakage risk prevention measures. Furthermore, the option may present significant administrative and regulatory challenges for Mexico, particularly during the introductory phase of its ETS.

4.4. Summary

Policy makers face trade-offs between competing objectives and have to decide depending on the specific circumstances. Each discussed measure has advantages and disadvantages. The preferability of one option is likely to depend on factors like the maturity of the scheme, the structure of the economy and political support for carbon pricing. For example, if acceptance of environmental regulation is high, political concerns are less relevant and Mexican policymakers might want to focus on the preservation of abatement incentives. During the phase-in of the Mexican ETS, political support and administrative simplicity might be more important.

Exemptions are easy to implement and provide strong leakage prevention but heavily undermine the initial objectives of carbon pricing. The exempted sectors face no price for the externalities of emitting, leaving them with no incentive to reduce emissions. Furthermore, the total emissions of these sectors are not capped, which might make a country fail its emissions targets. Thus, exemptions are likely to be an appropriate measure only at the early stage of the transition towards a comprehensive carbon market.

On the other side of the scale, BCAs strongly preserve abatement incentives but involve substantial administrative, political and potentially legal challenges. Demand-side abatement is attractive and low-carbon firms will have comparative advantages. Besides, BCAs extend the realm of carbon pricing and slightly reduce the asymmetry of global carbon pricing. Nevertheless, the administrative burden of determining the carbon content of imports pose serious challenges to the measure and political resistance by other jurisdictions might be significant at least to date. Therefore, BCAs might become more feasible once a larger share of the global economy moved towards carbon pricing.

Between the free allowances approaches, benchmarks are generally preferable compared to grandfathering in mature carbon markets. There are some additional administrative costs related to benchmarking but they seem manageable at a later stage of the Mexican ETS. In comparison to grandfathering, they provide stronger incentives to reduce emissions intensity. Between the two benchmarking approaches, advantages and disadvantages balance each other. OBA may prevent leakage more effectively but might result in lower demand-side abatement incentives through lower product prices. Furthermore, overall environmental outcomes may be jeopardised. The choice between FSB and OBA could differ depending on leakage risk, applying OBA to sectors at high risk of carbon leakage. For all free allowances approaches it is critical that the sectors eligible are selected carefully due to their risk of carbon leakage.

Linking could prevent leakage to key trading partners and enhance the depth of the carbon market. Connecting the Mexican ETS with California can prevent leakage to this state and furthermore increase market liquidity and abatement options. However, it would not provide protection from leakage to other jurisdictions such as the remaining US states.

Table 13 synthesises the discussed policy responses along with relevant decision criteria.

Table 13. Summary of policy responses to carbon leakage

	Grandfathering	FSB	OBA	Exemption	Rebates	BCA	Linking
Leakage prevention	Weak, unless closure rules and updating included	Weak, unless closure rules and updating included	Strong	Strong	Depends on design	Strong	Limited to the linked regions
Incentives to improve emissions intensity	In principle strong, but diluted when updating included	Preserved	Preserved	Not preserved	Preserved	Preserved	Preserved
Demand-side abatement incentives	Preserved	Preserved	Dulled, especially if applied too broadly	Removed	Depends on design	Preserved	Preserved
Administrative complexity	Easy to implement	Some complexity in establishing benchmarks	Some complexity in establishing benchmarks and costs in collecting output data	Easy to implement	Some complexity	Very complex	Some complexity
Risk of windfall profits	Some risk	Some risk	No	No	No	No	No
Risk to environmental outcome	No	No	Some risk, depending on design	Yes, exempt emissions uncapped	Depends on design	No	No
Political and legal challenges	No	No	No	No	No	Yes	Yes

Source: PMR (2015), Vivid Economics

5

Conclusions and Recommendations

5. Conclusions and recommendations

Empirical evidence suggests that carbon leakage has been limited to date, and the risk is likely to fall in the future as countries meet their Paris pledges. In the short term, international carbon leakage can happen through the loss of market share to international competitors. In the longer term, it can arise through the shifting of new investment and/or the relocation of production overseas. However, to date there is little evidence of leakage through either of these channels, which might be partly explained by leakage prevention mechanisms in other carbon pricing schemes and low carbon prices. Moreover, the risk of carbon leakage is likely to fall over time as more countries take action to reduce emissions.

Nonetheless, the serious political, economic and environmental implications of leakage risk suggest that it should be a concern for Mexican policymakers as they develop the national ETS. Carbon leakage can result in a loss of international competitiveness and domestic employment, while undermining the environmental impact of the carbon price. There is ex-ante evidence that some Mexican EITE sectors could be at risk of carbon leakage due to their:

– High emissions intensity, which can be defined as carbon emissions as a share of some metric of the value of production, such as GVA. This provides a measure of the potential increase in costs that firms may experience as a result of carbon pricing.

– High trade intensity, which can be defined as exports and imports as a share of total market size. A high trade intensity typically reflects a high degree of competition between domestic and foreign producers.

This analysis uses a dual methodology to identify ex ante carbon leakage risk. The economy-wide analysis employs a CGE model to simulate the production and flow of inputs between sectors and trade across regions. The sectoral analysis uses a range of international metrics and performs various sensitivity tests. The key results suggest:

– **The economy-wide analysis suggests that economy-wide impacts of the ETS are slightly negative but minimal, and these results do not account for broader economic or environmental impacts.** In the main scenario the ETS reduces GDP growth by 0.16 percentage points (MXN44,000m) or MXN325 (USD18) per capita in 2021 compared to the BAU. Furthermore, Mexico might profit from economic activity flowing into the country in 2021 due to higher carbon prices in other regions such as the EU. On a sectoral level, the 'chemical and plastic' sector was the most negatively affected by the ETS. However, these impacts do not account for the negative economic and environmental impacts associated with a failure to introduce carbon pricing.

– **Four sub-sectors are probably at high risk of carbon leakage: iron and steel, cement, glass and chemical industries.** Quantitative analysis suggests that these sub-sectors are at high risk[10]. However, abatement opportunities, likely cost pass-through capacity and the nature of trade exposure – competition is often with firms in countries which already price carbon – may help to reduce underlying leakage risk, especially in particular sub-sectors.

– **One sub-sector, pulp and paper, is likely to be at medium risk of leakage.** International metrics suggest that it is at risk, but this result is not robust to sensitivity tests. The sub-sector is identified as at risk under the EU ETS Phase III and Phase IV metrics, but on the margin between high and medium risk under the California metric, and sensitivity tests suggest that a classification of at high risk is not robust.

– **One sub-sector, lime, is unlikely to beat risk of carbon leakage.** The sub-sector is not identified at risk under the EU ETS Phase III and Phase IV metrics and identified at medium risk under the Californian metric. The sub-sector exhibits neither particularly high trade intensity nor emissions intensity and is therefore not considered to be at risk.

(10) The identification of the cement sub-sector under the EU Phase III metric depends on the carbon price assumption, but since the threshold is lower than the modelled carbon price for the Mexican ETS, the sub-sector will still be considered to be at risk.

– **Qualitative analysis of cost pass-through capacity and carbon cost exposure supplements and alters the quantitative part of the sectoral analysis.** The high market concentration in iron and steel, cement and parts of the chemical industry suggest carbon cost pass-through capacity, reducing the risk of carbon leakage. In the cement sub-sector, little international competition substantiates this conjecture and the comparison of its emissions intensity with other jurisdictions indicates that there is substantial abatement potential, further reducing the risk of carbon leakage.

To prevent carbon leakage in exposed sub-sectors, this study recommends a gradual approach to better target mitigation policies over time and increasing maturity of the carbon market. Sophisticated mitigation policies will not be feasible from early on due to administrative burden, data availability and potential lack of political support. Simpler policies can bridge the period until the requirements for more targeted approaches are fulfilled.

While the previous section discussed policy options in general, tailored recommendations for Mexico need to take the country's circumstances into account. It needs to take into account the current state of carbon pricing in Mexico, data availability and political feasibility. The optimal response to carbon leakage risk is not time-invariant but will develop due to the maturity of the domestic carbon market, environmental policies in other countries and changes in political and technical feasibility.

For the pilot phase, Mexico could start its ETS with grandfathering to support exposed sectors as a means of phasing in the carbon pricing mechanism.

For the pilot phase, Mexico could start its ETS with grandfathering to support exposed sectors as a means of phasing in the carbon pricing mechanism. Free provision of allowances is the easiest way to protect against carbon leakage. In the short term, for practical reasons, this could be achieved through grandfathering free allowances: providing allowances for free based on historic output. The data requirements and administrative ease of implementation make grandfathering a typical phase-in mechanism and would be implementable within the timeline of a planned start of the ETS. There is also a strong rationale for grandfathered support in Mexico as a form of transitional assistance, ensuring sector stakeholder buy-in during initial phases.

While grandfathering presents an attractive option for Mexico during the phase-in and early stages of an ETS, it is unlikely to address leakage concerns in the long run. The grandfathering approach does not effectively address output and carbon leakage in exposed sectors when the economy is either declining or growing quickly. Grandfathering is mainly attractive in the early phases of an ETS followed by a transition to other forms of carbon leakage risk reduction measures.

The beginning of the pilot phase should be used to collect more granular data to allow for detailed assessment. Data availability for some subsectors is currently limited but required to identify carbon leakage risk more accurately. Data for subsectors on the 5-digit SCIAN code level on trade and emissions intensity would enable Mexican policymakers to target support better and therefore reduce distortion and increase government revenue while providing effective carbon leakage mitigation for the subsector in need.

After data has been collected, Mexico should develop its threshold of the criteria to assess carbon leakage criteria. Experience from international thresholds can be utilised to find a suitable system – while learning the international lessons and keeping emissions intensity and trade exposure as the key metrics. The thresholds could be set on a combined metric (such as in the EU Phase IV) or consider a tiered approach (such as in California), allowing for more tailored but also more complex support. Furthermore, using emissions intensity and trade exposure could facilitate possible linking with other carbon markets as most markets today use these metrics.

At a later stage, Mexico could explore introducing a combination of fixed sector benchmarking and output-based allocation to target leakage risk more robustly. It can be attractive as it can account for varying levels of leakage risk between sectors:

- **Output-based allocation should be applied to sectors which have high risk of carbon leakage.** Output-based allocation is likely to result in maintained or increased output levels in Mexican EITE sectors despite competitive pressure from firms not covered by the carbon price, thereby offering strong leakage protection. This feature is likely to be particularly attractive given positive economic projections in Mexico. Furthermore, its prevalence in the California ETS suggests that it could be an attractive option to Mexico to facilitate scheme harmonisation (see Box 7).

- **Fixed-sector benchmarking should be applied to sectors with low to medium leakage exposure.** Maintaining some free allocation in these sectors is likely to be desirable to maintain stakeholder support. Importantly, however, this method has stronger abatement incentives than output-based allocation as a result of severing the link between individual firm emissions and allowances received.

The determination of which mechanism applies to each sector should be made on the basis of a comprehensive sub-sectoral carbon leakage risk assessment. The assessment of Mexican sectors in Section 3 suggests the following distribution of allowances after the pilot phase:

- **Output-based allocation for iron and steel, cement, glass and chemical industry.** These sub-sectors are found to be at high carbon leakage risk across all indicators and sensitivity tests and require a strong mitigation policy with strong leakage prevention.

- **Fixed-sector benchmarking for pulp and paper.** This sub-sector is only found to be at medium risk under the Californian metric if indirect emissions are excluded. Fixed-sector benchmarking might be sufficient to prevent carbon leakage and would provide better abatement incentives than OBA.

- **Full auctioning for the lime sector.** This sub-sector is found to be not at high risk under all three metrics, mainly due to its small trade intensity. The application of free allowances could generate windfall profits or dilute abatement incentives.

Box 7. Output-based allocation in the Californian ETS

California employs an output-based allocation mechanism to provide firms with a share of their emission permits free of charge. The level of assistance depends on the carbon leakage risks determined through the Californian three-tier metrics as described in Table 4. The so-called industry assistance factor (AF) depends on this leakage assessment and the compliance period, as summarised in Table 14.

Table 14. Industry assistance factor in the Californian ETS

Carbon leakage risk assessment	AF by compliance period		
	2013-2014	2015-2017	2018-2020
High	100%	100%	100%
Medium	100%	75%	50%
Low	100%	50%	30%

Note: After 2020, the AF will return to 100% irrespective of risk assessment
Source: CARB (2012)

Policymakers should keep the ETS under review, reducing the number of free allowances over time to increase Mexico's carbon revenue potential. If permits are not completely distributed free of charge, their sale can generate revenue. For example, over the period of the EU ETS Phase III (2013-2020), 57% of all allowances will be auctioned. Between 2013 and 2016, this generated revenue of nearly EUR15.8m (MXN370.6m) for EU member states[(11)]. Mexico could use its carbon revenue to reduce taxes elsewhere or provide financial support for the low-carbon transition. Box 8 summarises the revenue potential from the ETS. Mexico can enhance the effectiveness of a future ETS if it implements a system for periodic reviews. Such an adaptive management approach would include a process for monitoring policy effects and potentially amending policy parameters in the face of changing circumstances (GIZ 2017a).

Box 8. Potential revenues under the Mexican ETS

GIZ (2017) examined carbon pricing policies in Mexico , particularly by estimating carbon prices and revenues under a Mexican ETS. While the report assumes different emission reductions and employs a different methodology than the CGE modelling in Section 3.1, it can provide a rough idea of potential revenues under a Mexican ETS.

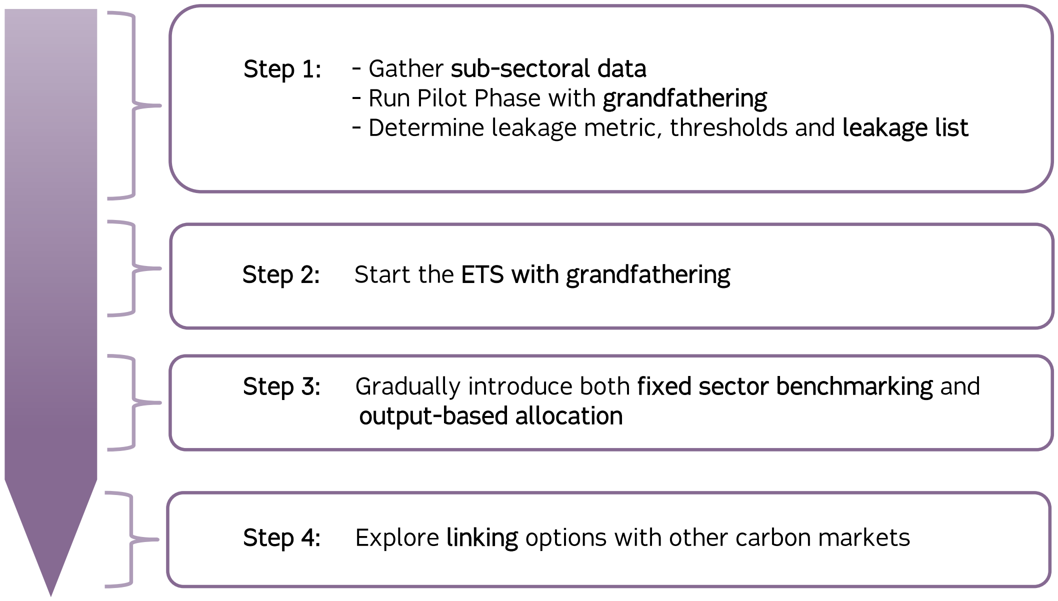
A shift from free allocation for industry to full auctioning would result in MXN115bn additional government revenue between 2017 and 2030. This volume is estimated under a scenario where the ETS that covers all sectors and the carbon tax is discontinued. Carbon revenues in this period would total to MXN270bn under full auctioning. In 2030, the ETS would generate revenues of MXN37bn, equivalent to around 1% of Mexico's total tax revenue in 2016 (constant Mexican Pesos).

The carbon revenues depend significantly on the choice of policy design and are highly uncertain. The main determinants for carbon revenues under the Mexican ETS are sectoral coverage, the level of auctioning and resulting carbon price. The latter will remain uncertain even after the policy design is completed, but the study provides a high-level estimation.

Once an ETS has been operational for some time, Mexico could explore linking its carbon market to others. Regional and global cooperation on abatement are key pillars of the Paris Agreement, and could be attractive to Mexico at the later stages of ETS implementation. Once Mexico's ETS has been sufficiently developed, it could consider more technical international mechanisms to improve environmental, economic and political outcomes. Figure 14 summarises the key recommendations for implementation of carbon leakage mitigation policies in Mexico.

(11) European Commission (2018). https://ec.europa.eu/clima/policies/ets/auctioning_en

Figure 14. Recommended roadmap for carbon leakage mitigation in Mexico



Source: Vivid Economics

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Appendix A: Guidance on sectoral analysis

This section provides guidance on the sectoral analysis conducted in Section 3.2. It includes a step-by-step instruction on the calculation of the three metrics, how to add new sectors to the workbook, and an overview on data sources and sector definitions.

1. Guidance on metric calculation

The assessment of carbon leakage risk under the three discussed metrics requires 17 steps within 5 parts:

a. Definition of scope
b. Data collection
c. Unit conversion
d. Metric calculation
e. Sensitivity tests

Definition of scope

1. Chose scope granularity according to data availability. The use of industry level codes to define sectors consistency across calculations. In Mexico, the most common system is the Sistema de Clasificación Industrial de América del Norte (SCIAN). The higher the digit level available, the higher the granularity of analysis.
2. Choose time period of analysis. Commonly, the most recent years are chosen. The use of multiple years makes the analysis robust to temporary fluctuations in production, trade or emissions. This analysis chose the period between 2014 and 2016.

Data collection and updating

3. Gather data according to required scope using the sources contained within Section 2 of this Annex, with key sources as follows:
    - Data on production, GVA and electricity data can be obtained from the National Institute of Statistics and Geography (INEGI).
    - Data on emissions can be obtained from SEMARNAT's emissions registry.
    - Data on electricity consumption can be obtained from the International Energy Agency's (IEA's) database. National sources might be also available.
    - Data on imports and exports can potentially be obtained from INEGI. This study uses the UN's Comtrade database because it simplifies the mapping of industry level and product level data. Trade data is often only available on a product level, the data therefore need to be matched to the respective industry.
4. Insert data into the following raw data sheets of the workbook:
    - R1. Electricity consumption
    - R2. Production and turnover
    - R3. Economic importance (GVA)
    - R6. Emissions data
    - R12. Comtrade (Import and export data)
5. Aggregate emissions data by sector/entity in W3.

Unit conversion

It is important that currency units and conversion factors are consistent within metrics. For more details, see Box 9.

6. Update R4 with currency conversion factors.
7. Update Table 1 of W2 to ensure year scope for currency averages is in line with scope of analysis.

Box 9. Conversion factors

The different variables usually come in different units and the metrics require certain units for their thresholds. The trade intensity metric is unitless and thus does not require a certain unit to be applied to the different metrics.

However, data on production is usually provided in the domestic currency, while trade data is often reported in US Dollars. For a volatile currency like Mexican Pesos, it is advisable to use an average exchange rate over the period of analysis. This increases the robustness of the risk assessment against currency fluctuations.

The emissions intensity metric requires specific units for all three metrics. For both EU ETS indicators, GVA must be converted into Euro values. Furthermore, the EU Phase III metric requires emissions to be in tons CO_2, while the EU Phase IV requires kilograms of CO_2. The Californian indicator requires GVA to be in US Dollar millions and emissions in tons of CO_2e. Similarly, the conversion of GVA into Euros and US Dollar should employ average exchange rates.

Metric calculation

Table 15 summarises the three methodologies used in this report. Key calculations are within sheet W1 of the workbook.

Table 15. The three methodologies have different criteria to determine sub-sectors at risk of carbon leakage

Scheme	Criteria	Definitions
EU ETS Phase III	Cost increase >30%; or Trade intensity >30% or Cost increase >5% and trade intensity >10% Qualitative assessment for borderline sub-sectors	Cost increase: [(assumed carbon price × emissions) + (electricity consumption × carbon intensity of production × carbon price)]/GVA) Trade intensity: (imports + exports)/imports + production)
EU ETS Phase IV	Carbon intensity × Trade intensity >0.2 Qualitative assessment for borderline sub-sectors	Trade intensity: (imports + exports)/(imports + production) Carbon intensity: kgCO_2/GVA
California	Emissions intensity tiers are: High: >10,000 t CO_2e per million dollars of revenue; Medium: 1,000-9,999 tCO_2e per million dollars of revenue; Low: 100-999 tCO_2e per million dollars of revenue, very low: <100 tCO_2e per million dollars of revenue. Trade intensity tiers are: High: >19%; Medium: 10-19%; Low: <10%.	Emissions intensity calculated as tonnes of CO_2e per million dollars of revenue metric Trade intensity: (imports + exports)/(imports + production)

Source: Vivid Economics

For the EU ETS Phase III methodology:

8. Calculate trade intensity (Table 1)
    - Insert data for new sectors under imports, exports (both from R12) and production (from R2) and with new sectors according to year/granularity scope
    - Calculate trade intensity for each year using the formula in Table 15 in Columns E-G
    - Calculate 3-year average in Column D
    - Column C will report whether at risk

9. Calculate cost increase metric (Table 2)
    - Insert data under GVA (R3), electricity consumption (R1) and production (R2) with new sectors according to year/granularity scope
    - Calculate total emissions: Add carbon emissions data (from R6) to the product of electricity consumption and grid emissions factor (Assumptions sheet) in Columns S-U
    - Calculate metric for each year using the formula in Table 15 in Columns E-G
    - Calculate 3-year average in Column D
    - Column C will report whether at risk

10. Calculate joint metric(Table 3)
    - Column C will report whether at risk on the basis of calculations in steps 9 and 10

For the EU ETS Phase IV methodology:

11. Calculate single metric (Table 5)
    - Calculate annual carbon intensity in Columns K-M by multiplying Total Emissions (Table 2) by kg conversion factor (Sheet W2, Table 2)
    - Multiply carbon intensity by trade intensity (from Table 1) in columns E-G
    - Calculate 3-year average in Column D
    - Column C will report whether at risk

For the California ETS methodology:

12. Calculate trade intensity (Table 6)
    - Insert data for new sectors under imports, exports (both from R12) and production (from R2) and with new sectors according to year/granularity scope
    - Calculate trade intensity for each year using the formula in Table 15 in Columns K-M
    - Calculate 3-year average in Column D
    - Classify the trade intensity in Column E-G according to the three categories in Table 15
    - Column C will report the level of risk

13. Calculate emissions intensity (Table 7)
    - Insert data under GVA (R3), electricity consumption (R1) and production (R2) with new sectors according to year/granularity scope
    - Calculate total emissions: Add greenhouse gas emissions data (from R6) to the product of electricity consumption and grid emissions factor (Assumptions sheet) in Columns O-Q
    - Calculate metric for each year using the formula in Table 15 in Columns J-N
    - Calculate 3-year average in Column D
    - Classify the emissions intensity in Column E-G according to the three categories in Table 15
    - Column C will report the level of risk

14. Combine trade intensity and emissions intensity (Table 8)
    - Combine the classification of trade intensity and emissions intensity to obtain the overall carbon leakage risk assessment
    - Column C will report the level of overall risk

Sensitivity tests

The work performs three sensitivity tests to ensure results are not driven by assumptions made in the analysis.

The sensitivity test on the carbon price assumption can only be performed for the EU Phase III metric. The rationale is that policymakers might want to assess carbon leakage for an expected carbon price lower than EUR30 (USD37). A sensitivity test could be to calculate the metric for a carbon price most likely to be expected in the Mexican ETS, for example taken from a modelling study. This report uses a reverted approach, calculating the carbon price threshold under which each sector would be identified at risk of carbon leakage.

15. To study the carbon leakage assessment under different carbon price assumptions:
    - Select an alternative carbon price for the analysis in the Assumptions sheet.
    - The calculation under the alternative carbon price assumption is already built in the W1. worksheet. The cost increase metric metrics is calculated in Column M-O of Table 2
    - Column K of Table 2 will report whether at risk under the cost increase metric, Column K or Table 3 whether at risk under the joint metric
    - The reverted approach is automatically calculated in Table 4

The sensitivity test on carbon-priced trade excludes imports from and exports to jurisdictions with comprehensive carbon pricing in place. On a country level, the data can be obtained from Comtrade as done for the initial assessment. For trade with US states, the US Census Bureau provides data on Mexican trade on an industry level. The decision on what trade to exclude depends on the state of carbon pricing in the respective jurisdiction. This report excludes the relevant US states and all EU ETS countries. A future assessment might want to exclude Chinese trade as well when China's ETS has matured.

16. To analyse the changes when trade with jurisdictions under a carbon pricing scheme is excluded:
    - Change the drop-down menu in the Assumptions sheet for EU and US states to TRUE
    - All metrics are updated automatically in W1. W0 provides a high-level overview, F1 illustrates the changes in the graphs

The sensitivity test on indirect emissions excludes emission from electricity consumption. The rationale is that the power sector might not pass through all costs of the carbon price to the sectors. Therefore, the sectors' carbon leakage risk might be lowered. For the execution of this sensitivity test, emissions intensity is calculated only with direct emissions, not including any emissions from electricity consumption.

17. To analyse carbon leakage risk without indirect emissions:
    - Add data on trade with US states for the new sectors in R14 and R15 and ensure it is included in the aggregation in W11. The data on trade with the EU will be automatically included when adding the Comtrade data for the new sector. US state and EU trade are then automatically aggregated in W12
    - Change the drop-down menu in the Assumptions sheet for Indirect Emissions to FALSE. Make sure the assumption on EU and US states is set to FALSE again
    - All metrics are updated automatically in W1. W0 provides a high-level overview, F1 illustrates the changes in the graphs

2. Sources

Table 16 summarises the data sources used in the sectoral analysis, Table 17 displays industry and product codes.

Table 16. Data sources

Data	Source	Unit	Granularity	Years
Imports and exports	Comtrade	USD	1-4-digit STIC codes	2004-2016
Gross Value Added	INEGI - Economic Information Bank	MXN	3-5-digit SCIAN codes	2004-2016
Production	INEGI - Economic Information Bank and Economic Census	MXN	3-5-digit SCIAN codes	2004-2016
Direct emissions	SEMARNAT emissions registry	tCO_2	6-digit SCIAN codes	2014-2016
Sectoral electricity consumption	INEGI – Economic Information Bank and SENER – Energy Information System	MWh	3-5-digit SCIAN codes	2004-2016
Carbon intensity of the Mexican electricity grid	IEA	g/kWh	Economy-wide	2016
Trade with US states	U.S. Census Bureau	USD	3-5-digit SCIAN codes	2012-2016
Employment	INEGI - Economic Information Bank		3-5-digit SCIAN codes	2004-2016

Source: Vivid Economics

Table 17. Industry and product codes

Variable	Classification system	Iron and steel	Lime	Cement	Glass	Pulp and paper	Chemical industry
Gross value added		3311	32741		3272	322	325
Production		3311	32741	32731	3272	322	325
Emissions	SCIAN	3311	32741, process emissions approximated	32731	3272	322	325
Electricity consumption		3311, approximated	n/a, approximated	32731, approximated	3272	322	325
Trade with US states		3311	3274, therefore excluded	3273, therefore excluded	3272	322	325
Imports and exports	SITC	67	6611	6612	664	25, 64	5

Source: Vivid Economics

Appendix B: Sectoral briefs

This section provides details on the analysis presented in Section 3.2.2 for the sectors iron and steel, lime, cement, glass, pulp and paper, and chemical industry. It includes general information on the sector and its production processes, competitive dynamics, emissions intensity and the final carbon leakage assessment.

1. Iron and steel

Sector Overview

Economic overview

The iron and steel sector contributes significantly to the Mexican economy and employment. It produced MXN157bn worth of goods in 2016, employing roughly 24,300 people(12). The sector's production declined by 9% in real terms between 2010 and 2016. In the same period, employment grew by 9%. In 2017, Mexico was the 14th biggest crude steel producer worldwide, producing 19.9m tons. In the same year, the sector represented 2.0% of the GDP, 12.9% of the manufacturing sector, and 6.9% of the industrial sector(13).

The sector is tightly linked to the construction sector. Around 62% of production was used in this sector in 2017. Other important consumers are the production of metallic products (20%), automobiles (11%) and mechanical machineries (8%)(13).

Products and processes

The most emissions intensive part of the steel production process is the melting of raw materials or scrap in furnaces. There are two main ways to produce steel: in integrated plants using Basic Oxygen Furnaces (BOFs) or using Electric Arc Furnaces (EAFs). The former uses iron ore and coking coal as raw materials to produce iron, while the latter mainly uses scrap metal to produce steel, requiring less energy. Mexico's share of EAF in steel production was at 69% in 2010, one of the highest globally(14). Liquid steel is cast into semi-finished product, and then rolled into flat or long steel products. Long steel products are used in construction, engineering, heavy machinery, rail track and other similar applications. Flat steel refers to sheets and plates of steel that are used for cladding, decking, shipbuilding, tubemaking, white goods, car bodies, and so on.

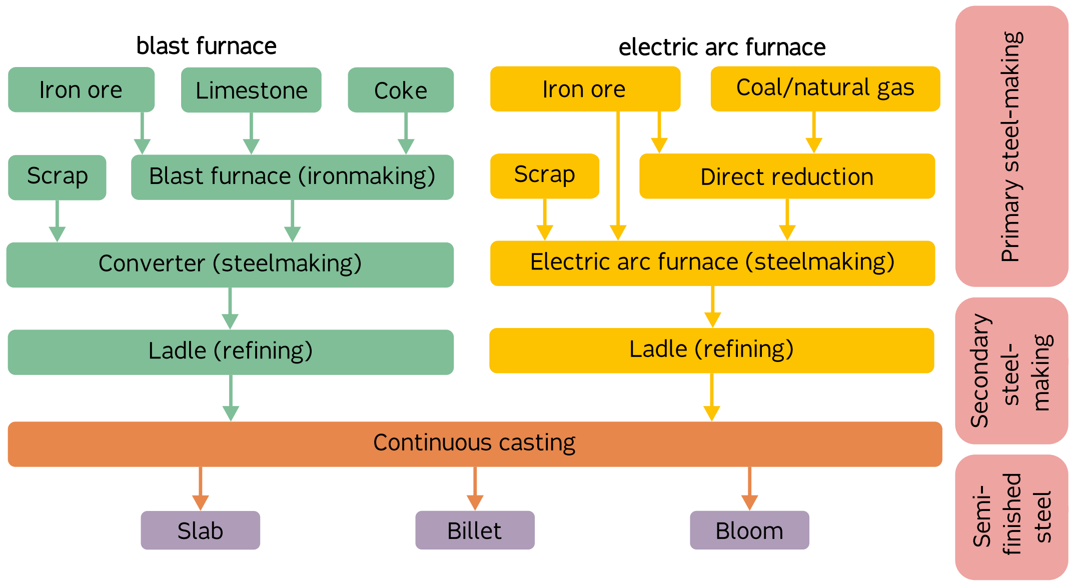
Figure 15 illustrates the production process of iron and steel.

(12) All data from the sources summarised in Table 16 unless indicated.

(13) CANACERO http://www.canacero.org.mx/Es/assets/infografia_canacero_2018.pdf

(14) Rojas-Cardenas, Jose C., et al. "Energy efficiency in the Mexican iron and steel industry from an international perspective." Journal of cleaner production 158 (2017): 335-348.

Figure 15. Primary steel may be produced either in Blast Furnaces or Electric Arc Furnaces



Source: Vivid Economics

Cost pass-through capacity

The domestic iron and steel market is highly concentrated. The five big players, Arcelor Mittal, AHMSA, Ternium México, DeACero, and TAMSA, account for around 85% of national steel production in 2011. The remaining market is distributed between ICH, Grupo San Luis, Aceros Corsa, Grupo SIMEC and other small players[(15)].

Capacity utilisation for crude steel in Mexico was around 67% in 2017. This figure is considerably low, suggesting a challenging competitive environment in the sector. The total installed capacity was 29.5m tons for crude steel in that year. Production is concentrated in the northern and central regions of the country.

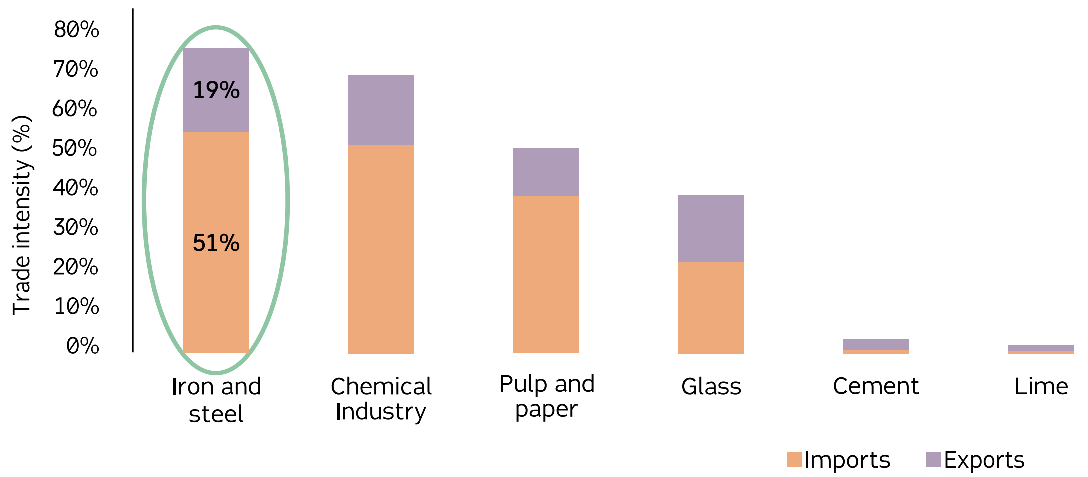
Studies on the EU ETS suggest high cost past-through in the sector in other jurisdictions. A high cost pass-through capacity is one of the main factors determining the potential impact of a carbon price on firms' competitiveness. An ex post analysis of the impacts of the EU ETS suggests that cost pass-through rate could be high, ranging from 75% to more than 100%[(16)].

Iron and steel exhibits high trade intensity, mainly due to import competition. Average trade intensity between 2016 and 2014 was 70% and almost two thirds due to imports. Mexico exported USD3bn (MXN65bn) and imported USD10bn (MXN200bn) in 2016, leading to a trade deficit of USD7bn. The sector's trade intensity is the highest of all analysed sectors, suggesting it is highly exposed to international competition. Figure 16 plots trade intensities for the six analysed sectors.

(15) Secreta but ría de Economía (2012). El Sector Siderúrgico en México. http://www.2006-2012.economia.gob.mx/files/Monografia_Sector_Acero.pdf

(16) CE Delft and Oeko-Institut (2015). Ex-post investigation of cost pass-through in the EU ETS. https://ec.europa.eu/clima/sites/clima/files/ets/revision/docs/cost_pass_through_en.pdf

Figure 16. Iron and steel is particularly trade exposed, with considerable exposure to competition from imports



Note: Trade intensity is calculated as (trade volume)/(domestic market size)
Source: Vivid Economics

Iron and steel exports are principally to countries without national carbon pricing mechanisms, increasing underlying leakage risk. Almost 70% of iron and steel exports are to the US, where no federal carbon price is in place. Also other main export destinations, such as Columbia or Canada, have no or only regional carbon pricing schemes implemented. In the domestic market, the US accounts for around half of all imports, followed by Japan (15%), both with no federal carbon prices. Other main competitors are South Korea and China, which have Emissions Trading Schemes (ETSs) implemented, the latter at a pilot phase. Table 18 depicts the top five import and export countries.

Table 18. Key import and export countries for the iron and steel sector in 2016

Rank	Imports (% share of total in brackets)	Exports (% share of total in brackets)
1	USA (46%)	USA (68%)
2	Japan (15%)	Columbia (6%)
3	South Korea (10%)	Canada (6%)
4	China (6%)	Kuwait (3%)
5	Canada (5%)	Guatemala (2%)

Source: Vivid Economics

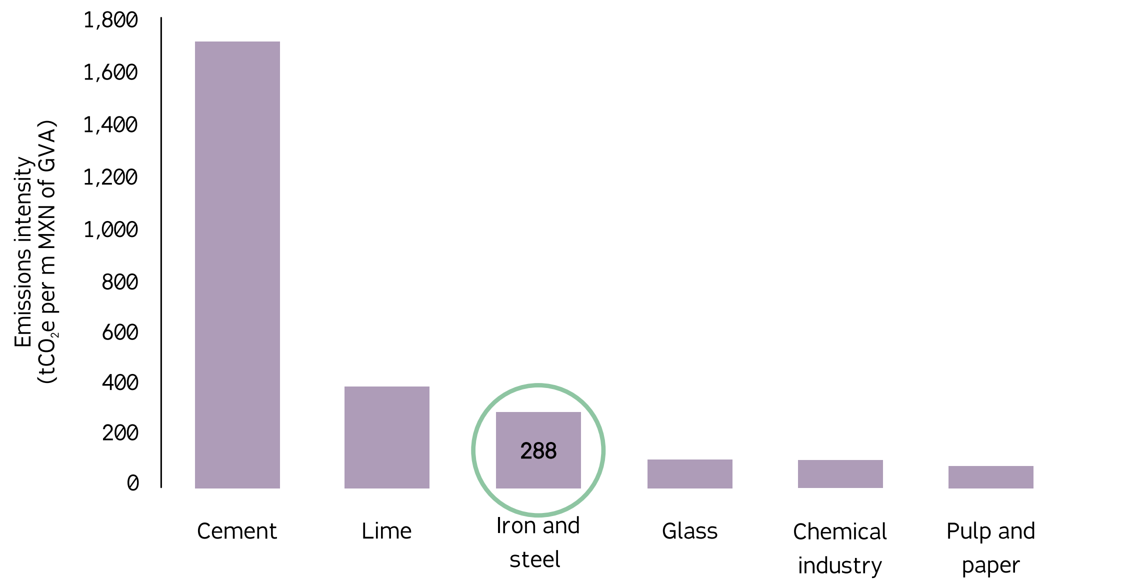
Carbon cost exposure

The iron and steel sector exhibits high emissions intensity, mostly due to direct emissions. Average emissions intensity as tons of CO_2-equivalent emissions per million MXN of Gross Value. Added (GVA) was 288 (4,501 tCO_2/USDm) between 2014 and 2016. This is substantially above the emissions intensity per GVA of 4,148 tCO_2/USDm(17), indicating some potential for abatement. Other studies find the sector to be less carbon intense than its US and Chinese counterparts, but assess potential for additional reductions. 93% of total emissions were direct emissions while the remainder stemmed from electricity consumption. The sector reduced its emissions intensity by 22% between 2014 and 2016. Figure 17 displays emissions intensity for all six sectors in 2016.

There are two key abatement opportunities in the production of iron and steel:

1. **Implementation of alternatives to fossil fuel-based electricity generation:** Plants with EAFs tend to generate their own electricity on-site and could substitute to less emissions-intensive fuel sources. Mexico's steel industry exhibits a high share of natural gas in its final energy use, but coke is the second biggest fuel[14]. Producers could invest in on-site renewables for electricity where geographical conditions are favourable.
2. **Expand the use of direct reduced iron (DRI) in EAFs as an alternative to BOFs:** The use of DRI in EAFs could serve as a less emissions-intensive alternative to BOFs. Use of DRI requires low initial investment and direct reduction plants have lower operating costs than integrated steel plants. The supply of DRI is more adaptable than scrap steel and more carbon-efficient than BOF steel production. This method can reduce CO_2 emissions by 50% relative to the BOF method(18).

Figure 17. Iron and steel exhibits the second highest emissions intensity out of the 6 sectors



Source: Vivid Economics

(17) ARB (2010). Appendix K Leakage Analysis. https://www.arb.ca.gov/regact/2010/capandtrade10/capv4appk.pdf
(18) Columbia Climate Center (2012). Mitigating Iron and Steel Emissions. THE GNCS FACTSHEETS, Columbia Climate Center, 2008–2009.

Carbon leakage risk assessment

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the iron and steel sector produced the following results:

1. California metric: iron and steel identified to exhibit 'high' leakage risk based on high trade intensity;
2. EU ETS Phase III metric: iron and steel identified based trade intensity;
3. EU ETS Phase IV metric: iron and steel identified.

Table 19. International metrics clearly identify the iron and steel sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the iron and steel sector as at risk. Changes in assumptions on carbon price, exclusion of trade with jurisdictions with carbon pricing in place, and indirect emissions do not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the low capacity rate and the high trade exposure, especially to jurisdictions without carbon pricing suggest that the sector would not be able to substantially pass through carbon costs. This could aggravate carbon leakage risk.

– the high market concentration and tentative evidence from other jurisdictions suggest that cost pass-through capacity may be high. Furthermore, there are a range of abatement options available for the sector which could reduce emissions intensity and therefore carbon costs. This could reduce carbon leakage risk.

2. Lime

Sector Overview

Economic overview

Lime production is a small sector of the Mexican economy, growing less than the overall economy in recent years. Sectoral production was MXN6bn in 2016, and it employed roughly 3,300 people[19]. The sector has been growing by 6% in real terms between 2010 and 2016, while the whole economy grew by 18%. Employment declined by 8% in the same period.

Lime is used in multiple other sectors, most notably in construction, metallurgy, and agriculture. Its chemical properties make it an important product for various extraction processes such as mining or acquisition of petroleum. Its products find use across various sectors in the Mexican economy[20].

(19) All data from the sources summarised in Table 16 unless indicated
(20) Asociación Nacional de Fabricantes de Cal, A.C. http://anfacal.org/pages/usos-y-aplicaciones-de-la-cal.php

Products and processes

The most emissions intensive step in lime production is the heating of raw materials in kilns. Lime is made from natural deposits of limestone or chalk. Quarrying, transport and crushing are the three initial steps in preparation. Production of lime then involves a chemical reaction triggered by application of heat, which is carried out in kilns at temperatures above 800ºC. Direct carbon emissions occur during this process as a by-product of the calcination of limestone.

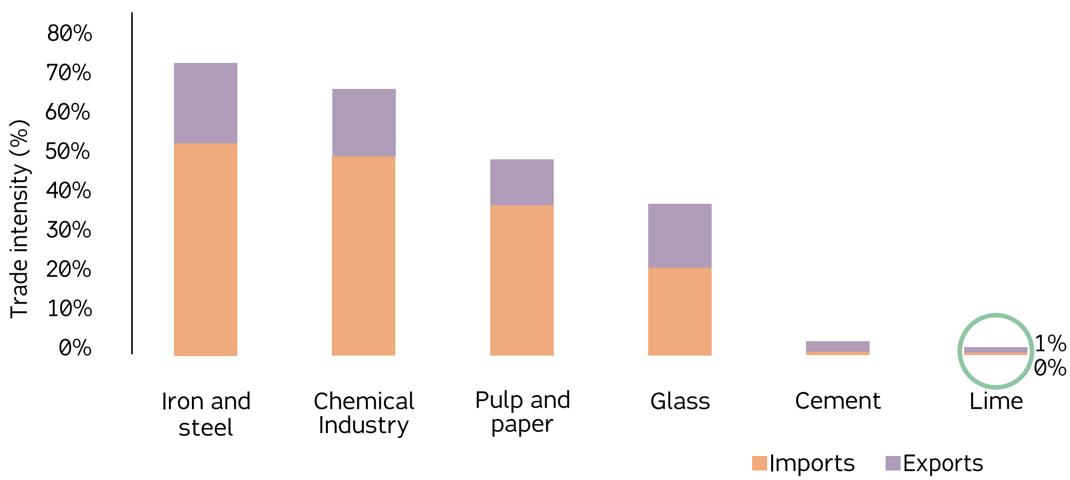
There are three key types of lime: uncalcined calcium carbonate, burnt lime or quicklime, and hydrated lime. Hydrated lime is used, for example, to increase the workability of lime mortar, and is produced through the combination of quicklime with water.

Cost pass-through capacity

The Mexican lime market is dominated by three big players, who constitute most of the domestic market. Grupo Calidra alone owns 22 firms and accounts for around one third of the market[21]. In total, there are 66 lime factories in the country, most of them with a small number of employees. The lime sector experienced substantial consolidation in recent years as have been absorbed by large players in the past. This high level of market concentration suggests that there might be some potential to pass though carbon costs.

Lime is little traded across borders, and thus exhibits low trade intensity. Transportation costs are often prohibitive in the sector, making domestic competition dynamics more important for the industry's performance than foreign competition. Average trade intensity between 2014 and 2016 was 2%, almost exclusively due to exports. Figure 18 plots trade intensities for the six analysed sectors.

Figure 18. Lime is traded very little across borders



Trade intensity is calculated as (trade volume)/(domestic market size); difference between trade intensity and import and export share is due to rounding.
Source: Vivid Economics

Most of the sector's little trade is with jurisdictions without a carbon price, increasing the underlying carbon leakage risk. In 2016, 58% of exports were sent to the US. The second biggest destination is Chile, accounting for around one third of exports, a country without a carbon pricing scheme. Import competition is dominated by the US, who accounts for more than 90% of imports, due to the overall low import volume this is less significant to the industry. However, due to the low total volume of trade in the lime sector, the overall risk from international competition is less severe. Table 20 depicts the top five import and export countries in the lime sector.

(21) Grupo Calidra. www.calidra.com

Table 20. Key import and export countries for the lime sector in 2016

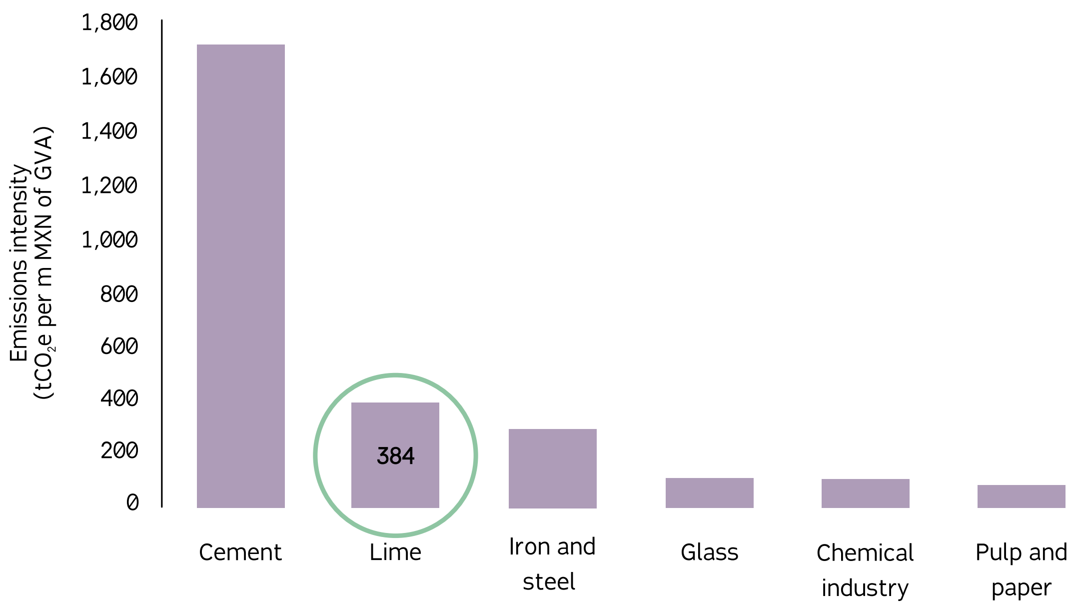
Rank	Imports (% share of total in brackets)	Exports (% share of total in brackets)
1	USA (46%)	USA (68%)
2	Japan (15%)	Columbia (6%)
3	South Korea (10%)	Canada (6%)
4	China (6%)	Kuwait (3%)
5	Canada (5%)	Guatemala (2%)

Source: Vivid Economics

Carbon cost exposure

The lime sector exhibits medium-high low emissions intensity, significantly lower than other non-metallic minerals such as cement. Average emissions intensity as tons of CO_2-equivalent emissions per million MXN of Gross Value Added (GVA) was 384 (6,006tCO_2/USDm) between 2014 and 2016[22]. The sector's emissions intensity remained mostly constant between 2014 and 2016. Figure 19 displays emissions intensity for all six sectors in 2016.

Figure 19. Lime's emissions intensity is assessed as medium under the Californian metrics



Source: Vivid Economics

(22) SEMARNAT's emissions registry entails no process emissions for lime, even though this process is considered highly carbon intense. Lime's process emissions are estimated by assuming that the share of process emissions in total emissions equals that of European lime production. In Europe, process emissions represent 38% of total emissions (EuLa (2014). A Competitive and Efficient Lime Industry. https://www.eula.eu/documents/competitive-and-efficient-lime-industry-cornerstone-sustainable-europe-lime-roadmap-0). Nevertheless, the Californian lime sector exhibits a significantly higher emissions intensity of 29,398 tCO_2/USDm, indicating that a significant amount of lime emissions are not captured.

There are three key abatement opportunities in the production of lime:

1. Adoption of the most efficient lime kilns in use: The most advanced lime kilns in the EU operate close to thermodynamic minimum and Mexican producers could aim for similar progress. Vertical and parallel flow regenerative kilns are the most efficient. The replacement of horizontal kilns with vertical kilns is one carbon abatement option; however, less than 10% of the kilns remaining in Europe are horizontal[23]. Kiln replacement is capital-intensive and may not be feasible for small-size lime producers, but larger players in the market may have the capacity to make these investments.
2. Use of preheaters and waste heat recovery: Waste heat recovery technology could reduce energy consumption and associated costs. These measures include improving the internal use of heat in kilns and the export of residual heat. Whether these measures are economically attractive is likely to depend on individual producers
3. Fuel switching to natural gas or biomass: Some carbon emissions may be saved by fuel switching to natural gas or biomass. Switching to gas could positively impact the quality of lime produced but is often more expensive than production using solid fuels, and may not be feasible for all producers in the lime sector.

Carbon leakage risk assessment

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the lime sector produced the following results:

1. California metric: lime identified to exhibit 'medium' leakage risk based on medium emissions intensity;
2. EU ETS Phase III metric: lime not identified;
3. EU ETS Phase IV metric: lime not identified.

Table 21. International metrics do not identify the lime sector to be at (high) risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	Low	Medium	Medium	No	No	No	No	No

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the lime sector as not at (high) risk. Sensitivity analysis of results to assumptions on carbon price and exclusion of trade with jurisdictions with carbon pricing in place does not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

- the substantially lower emissions intensity compared to other jurisdictions indicates that emissions might not have been reported comprehensively for the sector. If actual emissions intensity is significantly higher, this would increase carbon leakage risk.
- the high market concentration and the marginal trade intensity suggests that cost pass-through capacity may be high. This could reduce carbon leakage risk.

3. Cement

Sector Overview

Economic overview

The cement sector is relatively small in Mexico but has been growing fast in the past. It produced MXN82bn

(23) Stork, M., Meindertsma, W., Overgaag, M., & Neeils, M. (2014). A competitive and efficient lime industry. Ecofys.

worth of goods in 2016 and employed roughly 7,400 people[24]. Production increased by 28% in real terms between 2010 and 2016, substantially above the whole economy's growth of 18% in the same period. The number of plants decreased slightly from 37 in 2005 to 34 in 2015. Employment increased as well, but at a slower pace at 2% in the same period.

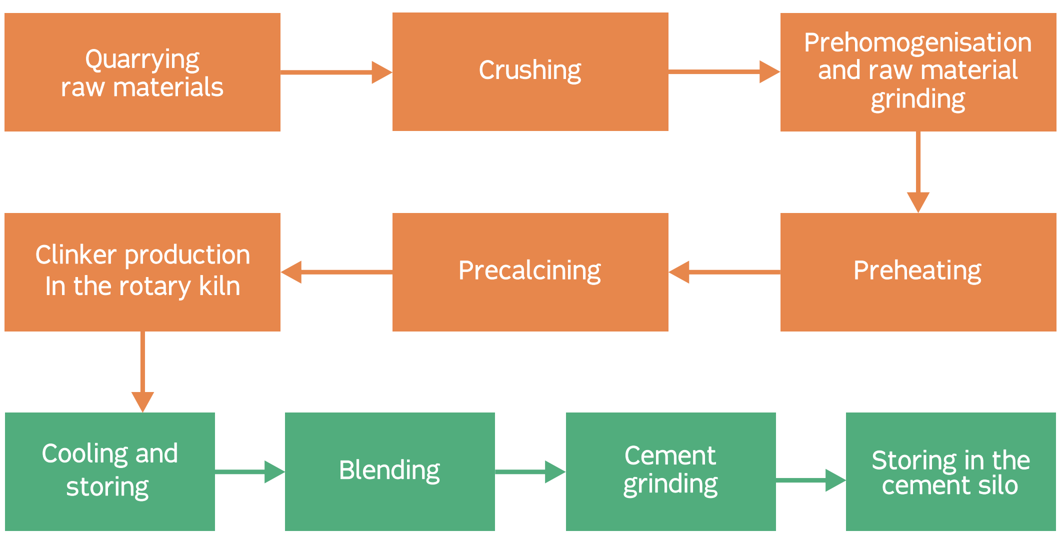
The sector is tightly linked to the construction sector and therefore dependent on its performance. Cement is one of the most important products in private and public construction. The tight link to construction makes the cement industry also dependent on the general economic environment. Other sectors providing materials for the construction sector, such as steel, glass, aluminium, and wood, are themselves dependent on the cement industry[25].

Products and processes

The key emissions intensive process in cement production is clinker production. Raw materials, primarily limestone and clay, are first blended and ground, then heated in kilns at temperatures of up to 1,500ºC to make clinker. The burning process takes several hours and produces clinker in the form of spherical pebbles.

Cement types are generally demarked by clinker concentration ratios. Clinker is ground and mixed with a small amount of gypsum or anhydrite to make Portland cement, which constituted around 80% of Mexican cement production in 2015. To make blended cement, clinker and gypsum or anhydrite is ground with materials such as fly ash, limestone dust and granulated blast-furnace slag. The lower proportions of clinker in blended cements make them a less emissions-intensive product. An integrated plant produces its own clinker and, from this, cement; whereas a grinding plant buys clinker from other producers and grinds it into cement. Around three-quarters of cement in Mexico is sold in 50 or 25kg sacks, leading to high distribution costs. Figure 20 illustrates the production process of cement.

Figure 20. The production of clinker is the most energy intensive process within cement production



Source: Vivid Economics

(24) All data from the sources summarised in Table 16 unless indicated

(25) Vásquez, Belem, and Salvador Corrales (2016). "The Cement Industry in Mexico: An Analysis of its Determinants.", Problemas del Desarrollo 48 (188)

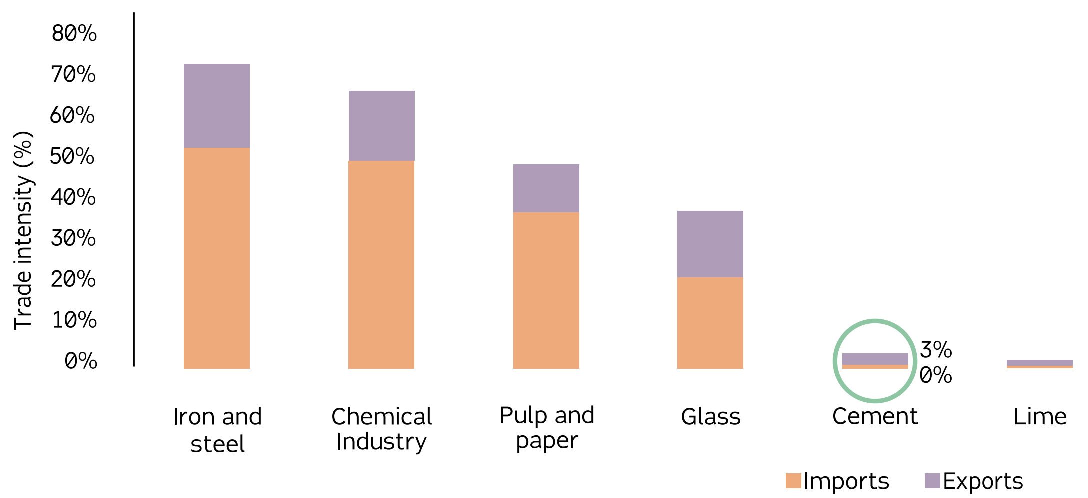
Cost pass-through capacity

Domestic competition in the Mexican cement industry is highly concentrated. The market is concentrated around a few large players. Mergers and acquisitions, some of them from international cement companies, have led to further agglomeration in the past. The largest producer Cemex accounts for almost 50% of domestic sales and production. An earlier analysis by Ghemawat and Thomas (2006) finds that the increased share of multinationals in the domestic market led to an increase in profitability in the past, not driven by cost decreases or efficiency increases but pricing power[26]. Capital utilisation remained relatively constantly high in recent years and was 84% in 2015[27], suggesting a dynamic sector.

Studies on the EU ETS suggest low cost past-through in the cement sector in other jurisdictions. Cost pass-through capacity is one of the main factors determining the potential impact of a carbon price on firms' competitiveness. An ex post analysis of the impacts of the EU ETS suggests that cost pass-through rate could be low, ranging from 20% to 40%[28]. This suggests that an increase in production costs through a carbon price may mainly be borne by the sector itself.

This is also reflected in the low trade intensity of the sector. Average trade intensity between 2014 and 2016 was 3%, mainly driven by exports. The number is in line with global pattern of cement trade, as only 3% of world cement production is traded across borders due to high transport costs as a share of GVA. In 2016, Mexico exported USD102m (MXN2bn) and imported USD19m (MXN374m) in 2016, leading to a trade surplus of USD83m. Figure 21 plots trade intensities for the six analysed sectors.

Figure 21. Finished cement products are traded little across borders



Note: Trade intensity is calculated as (trade volume)/(domestic market size)
Source: Vivid Economics

(26) Ghemawat, Pankaj and Catherine Thomas (2005), Multinational Agglomeration in the Cement Industry: Patterns, Drivers, and Performance Implications, Harvard Business School (consulted February 2006), available at: <www.rotman.utoronto.cal~baum/workshop/Ghemawat_worksho.pdf>

(27) Vásquez, Belem, and Salvador Corrales (2016). "The Cement Industry in Mexico: An Analysis of its Determinants.", Problemas del Desarrollo 48 (188)

(28) CE Delft and Oeko-Institut (2015). Ex-post investigation of cost pass-through in the EU ETS. https://ec.europa.eu/clima/sites/clima/files/ets/revision/docs/cost_pass_through_en.pdf

Import and export competition are dominated by the US, a country without federal carbon price, but less than in other sectors. The US accounted for half of all cement imports in 2016. The remaining imports mostly stem from China and EU member states, all of which have an ETS implemented. Mexican cement exports go almost exclusively to countries without federal carbon pricing schemes, only some US states have policies implemented. The relevance of both import and export competition are limited by the low absolute volume of trade in the sector. Table 22 depicts the top five import and export countries.

Table 22. Key import and export countries for the cement sector in 2016

Rank	Imports (% share of total in brackets)	Exports (% share of total in brackets)
1	USA (50%)	USA (65%)
2	China (16%)	Belize (10%)
3	Netherlands (13%)	Brazil (7%)
4	Croatia (11%)	Guatemala (5%)
5	Poland (4%)	Haiti (4%)

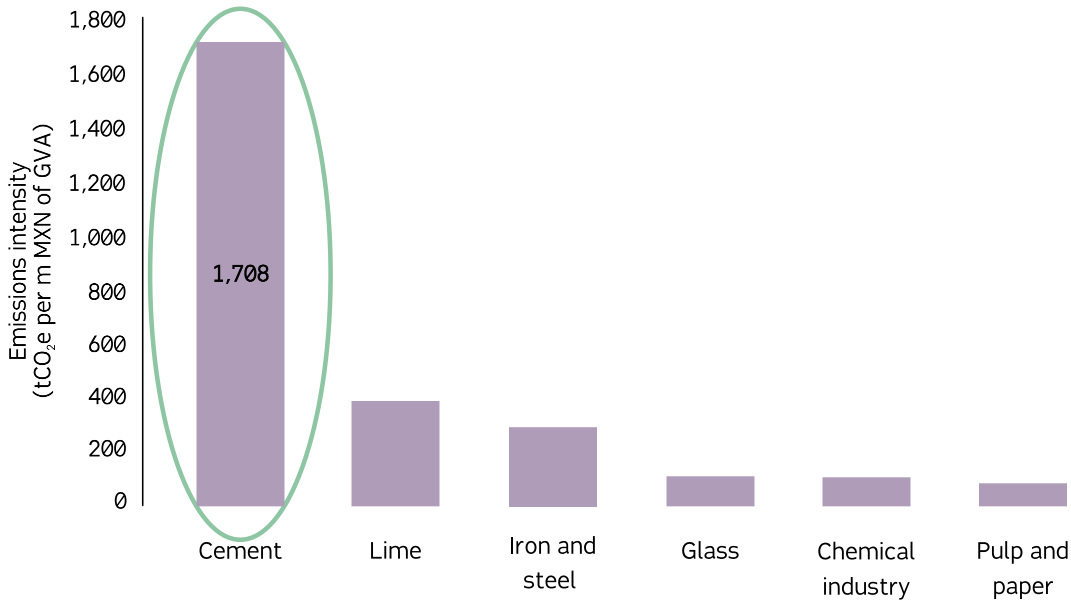
Source: Vivid Economics

Carbon cost exposure

The cement sector exhibits high emissions intensity, almost six times higher than the second most emissions-intense sector analysed. Average emissions intensity as tons of CO_2-equivalent emissions per million MXN of Gross Value Added (GVA) was 1,708(26,687 tCO_2/USDm) between 2014 and 2016. Californian cement production exhibits emissions intensity of only 13,744tCO_2/USDm[29], suggesting some scope to reduce emissions intensity in Mexico. 89% of total emissions were direct emissions while the remainder stemmed from electricity consumption. The sector reduced its emissions intensity by 19% between 2014 and 2016. Figure 22 displays emissions intensity for all six sectors in 2016.

(29) ARB (2010). Appendix K Leakage Analysis. https://www.arb.ca.gov/regact/2010/capandtrade10/capv4appk.pdf

Figure 22. Cement exhibits a six times higher emissions intensity than the second most intensive sector



Source: Vivid Economics

Abatement could reduce the sector's exposure to carbon pricing. There are two key abatement opportunities in the production of cement[30]:

1. **Increasing the production of blended cement:** Blended cement contains smaller proportions of clinker and thus reduces the energy needed in production, but opportunities are limited by procurement process specifications. Fly ash and slag cements have lower early strength but demonstrate higher long-term strength, which makes them preferable for dams, bridges and other large infrastructure[31]. By specifying a lower minimum clinker content, procurement processes can incentivise the production of more blended cement. However, this may be limited by varying regional availability of granulated blast furnace slag and fly ash.
2. **Transitioning to alternative fuels like biomass, and solid recovered fuel (SRF) from waste.** The industry could standardise SRF uptake, as this will improve efficiency regardless of carbon pricing. Facilities that have installed waste heat recovery facilities could become partly self-sufficient in terms of power consumption. Thus, even in the absence of carbon pricing, the industry could improve efficiency through higher uptake of co-incineration.

Carbon leakage risk assessment

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the cement sector produced the following results:

1. California metric: cement identified to exhibit 'high' leakage risk based on high emissions intensity.
2. EU ETS Phase III metric: cement identified based on the cost increase metric;
3. EU ETS Phase IV metric: cement identified

(30) CSI/ECRA. (2017). Development of State of the Art Techniques in Cement Manufacturing: Trying to look ahead. European Cement Research Academy, (March), 1–190.
(31) WBCSD, & IEA. (2009). Cement Technology Roadmap 2009: Carbon emissions reductions up to 2050, 36. https://doi.org/978-3-940388-47-6

Table 23. International metrics clearly identify the cement sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	Trade intensity	Emissions intensity	Level of Risk	Trade intensity	Cost Increase	Joint Metric	Identified	Identified
Initial Assessment	Low	High	High	No	Yes	No	Yes	Yes

Source: Vivid Economics

Cement's identification in the EU ETS Phase III metric is sensitive to the carbon price assumption. Only above an assumed carbon price of EUR10.82 (USD12.79) would the sector be identified. Sensitivity analysis of results to assumptions on not carbon-priced trade exposure and indirect emissions does not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

– the low capacity rate and the high trade exposure, especially to jurisdictions without carbon pricing suggest that the sector would not be able to substantially pass through carbon costs. It is reinforced by tentative evidence from other jurisdictions on carbon cost pass-through. This could aggravate carbon leakage risk.

– the high market concentration and low international competition suggest that cost pass-through capacity may be high. The higher emissions intensity compared to other jurisdiction and the availability of a range of abatement options available for the sector suggests room for abatement. This could reduce carbon leakage risk.

4. Glass

Sector Overview

Economic overview

The glass sector increased its contribution to the Mexican economy and employment substantially in recent years. In 2016, the sector produced MXN59bn worth of goods, employing roughly 32,000 people[32]. Production increased by 23% in real terms between 2010 and 2016; more than the average economy, which grew by 18% in the same period. Employment grew by 11% in the same period.

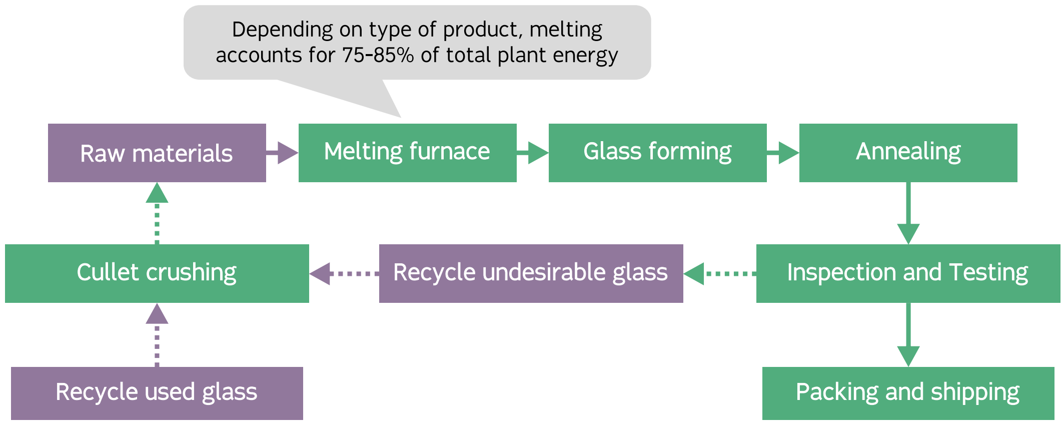
Products and processes

Within the glass industry, products and production processes vary substantially. In Mexico, the container glass constitutes more than half of the sector (54%).Flat glass accounts for around one-third of the market (31%). Fibreglass represents 5% of the sector but is beyond the scope of this brief.

The most emissions-intensive step in the glass production process is the melting and refining of raw materials in melting furnaces. This process accounts for 75–85% of total energy consumption, with furnaces operating at temperatures of up to 1,600–1,700ºC. Furnaces require continual operation. As a result, production is not flexible and cannot adjust quickly in response to energy price or exchange rate fluctuations. Figure 23 illustrates the key production processes of glass. Energy use in glass forming is variable by product, but the energy required to heat and maintain the melting furnaces and refining is comparable across sub-sectors[33].

(32) All data from the sources summarised in Table 16 unless indicated.
(33) Forming, melting and refining are processes in glass production.

Figure 23. The largest source of emissions is from fossil fuel combustion used to melt raw materials



Source: Vivid Economics

Cost pass-through capacity

Acquisitions and investments in the Mexican glass sector indicate a dynamic sector. The biggest glass producer in Mexico, Vitro S.A.B., has recently been sold to Owens-Illinois Inc. The American company invested in new factories in Mexico to accompany growing demand(34). In addition, the French glass bottle producer Saverglass recently opened a new production plant in Mexico worth USD120m(35). The developments indicate the Mexican glass industry to be a growing and dynamic sector.

Studies on the EU ETS suggest high cost past-through in the sector in other jurisdictions. A high cost pass-through capacity is one of the main factors determining the potential impact of a carbon price on firms' competitiveness. An ex post analysis of the impacts of the EU ETS suggests that cost pass-through rate for container glass could be high, ranging from 40% in France to 60-100% in Italy(36).

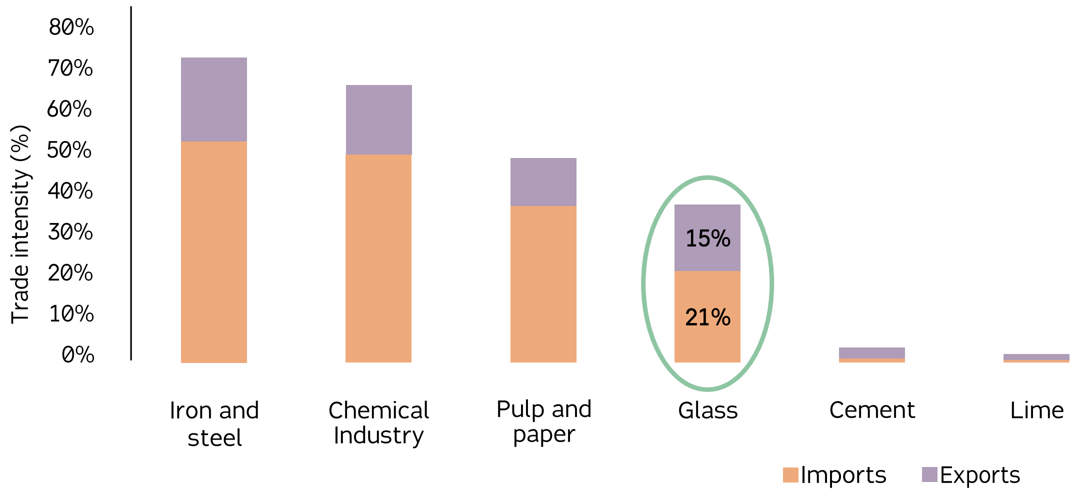
The glass sector exhibits high trade intensity, mainly due to import competition. Average trade intensity was 37% between 2014 and 2016, around 60% due to imports. In 2016, Mexico exported USD640m (MXN13bn) and imported USD946bm (MXN19bn) in 2016, leading to a trade deficit of USD306m. Figure 24 plots trade intensities for the six analysed sectors.

(34) Mexico News Daily (2015). Mexico's largest glass producer sold. https://mexiconewsdaily.com/news/mexicos-largest-glass-producer-sold/

(35) MexicoNow (2018). French premium glass bottle producer Saverglass to open USD120 million plant in Jalisco. https://mexico-now.com/index.php/article/3989-french-premium-glass-bottle-producer-saverglass-to-open-plant-in-jalisco-by-june

(36) CE Delft and Oeko-Institut (2015). Ex-post investigation of cost pass-through in the EU ETS. https://ec.europa.eu/clima/sites/clima/files/ets/revision/docs/cost_pass_through_en.pdf

Figure 24. Glass is highly trade exposed, with a higher share of imports



Source: Vivid Economics

Almost all exports and most of imports are with the US, a country with no federal carbon price in place, increasing underlying carbon leakage risk. 88% of exports are sent to the northern neighbour, all other destinations play only a marginal role. Imports are more diversified; 60% are imported from the US. The second biggest import competitor is China, whose national ETS is currently in a pilot phase and who accounts for roughly one-fifth of imports. Table 24 depicts the top five import and export countries.

Table 24. Key import and export countries for the glass sector in 2016

Rank	Imports (% share of total in brackets)	Exports (% share of total in brackets)
1	USA (60%)	USA (88%)
2	China (19%)	Canada (1%)
3	Brazil (4%)	Columbia (1%)
4	Germany (2%)	Peru (1%)
5	South Korea (2%)	Brazil (1%)

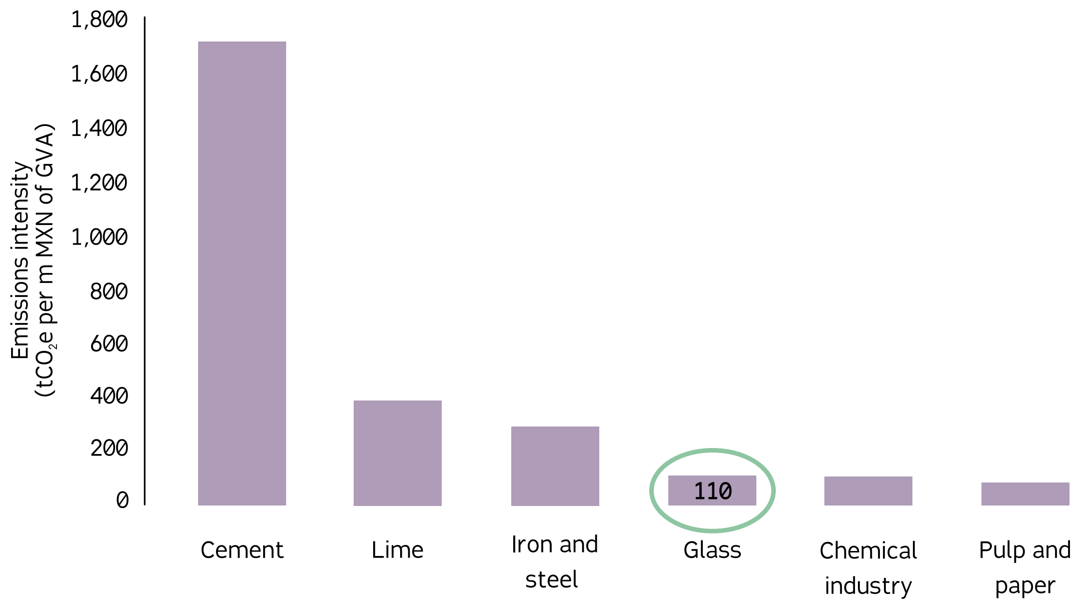
Source: Vivid Economics

Carbon cost exposure

The glass sector exhibits relatively low emissions intensity compared to other analysed sectors. Average emissions intensity as tons of CO_2-equivalent emissions per million MXN of Gross Value Added (GVA) was 110 (1,719 tCO_2/USDm) between 2014 and 2016. This is close to the Californian emissions intensity in flat glass of 1,708 tCO_2/USDm and substantially lower than the one for flat glass at 3,444 tCO_2/USDm[(37)], indicating a relatively efficient production process on average. 82% of total emissions were direct emissions while the remainder stemmed from electricity consumption. The sector's emissions intensity remained relatively constant between 2014 and 2016. Figure 25 displays emissions intensity for all six sectors in 2016.

(37) ARB (2010). Appendix K Leakage Analysis. https://www.arb.ca.gov/regact/2010/capandtrade10/capv4appk.pdf

Figure 25. Glass' emissions intensity is assessed as medium under the Californian metrics



Source: Vivid Economics

Realisation of abatement opportunities could result in lower energy costs and emissions intensities, which could drive down the cost increase experienced from potential carbon pricing mechanisms in Mexico. There are three key abatement opportunities in the production of glass:

1. **Improving the energy efficiency of melting furnaces, including furnace waste-heat recovery:** Waste-heat recovery can significantly decrease energy demand and associated costs. Recovered heat can be used to preheat the batch and cullet, but retrofitting preheaters may be economically challenging due to high capital costs. Additional techniques that could increase the energy efficiency of melting furnaces include using more effective sensors, control systems and refractors. Energy management systems implemented across facilities can help identify shortcomings in energy efficiency performance.
2. **Decreasing fossil fuel consumption and use of electricity through the use of alternative, less emissions-intensive sources:** Fuel substitution options are limited by a variety of feedstocks used to produce biogas; however, other renewable energy options could be viable for larger plants. While less emissions-intensive, the variety of feedstock used in biomass production means that methane contents vary and thereby complicate combustion, which can further impact product quality. As of now, applications of biogas are correspondingly limited. Installation of renewable generation at larger facilities may be economically viable if economic and geographic conditions are favourable. For smaller firms it may be costly to implement new fuel switching technologies on the required scale.
3. **Expanding the use of recycled glass in production:** A major source of abatement could be an increased use of recycled glass. The use of cullet for hollow glass could significantly reduce production costs, energy consumption and emissions. This requires the elevation of industrial and domestic recycling rates.

Carbon leakage risk assessment

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the glass sector produced the following results:

1. California metric: glass identified to exhibit 'high' leakage risk based on high trade intensity;
2. EU ETS Phase III metric: glass identified based trade intensity;
3. EU ETS Phase IV metric: glass identified.

Table 25. International carbon leakage risk identification metrics clearly identify the glass sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the glass sector as at risk. Changes in assumptions on carbon price, exclusion of trade with jurisdictions with carbon pricing in place, and indirect emissions do not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

- the low emissions intensity compared to other jurisdictions indicates that abatement options have already been utilised, lowing the potential for additional abatement. Furthermore, most of the sector's trade is with jurisdictions without carbon pricing. This could aggravate carbon leakage risk.
- the tentative evidence from other jurisdictions on carbon cost pass-through suggests that cost pass-through capacity may be high. The past growth and the recent investments suggest a dynamic sector. This could reduce carbon leakage risk.

5. Pulp and paper

Sector Overview

Economic overview

The pulp and paper sector contributes significantly to the Mexican economy and employment. It produced MXN187bn worth of goods in 2016 and employed roughly 71,100 people[38]. The sector has been growing by 11% between 2010 and 2016, less than the overall economy's growth of 18%. Employment has been growing by 2% between 2016 and 2010 in the same period.

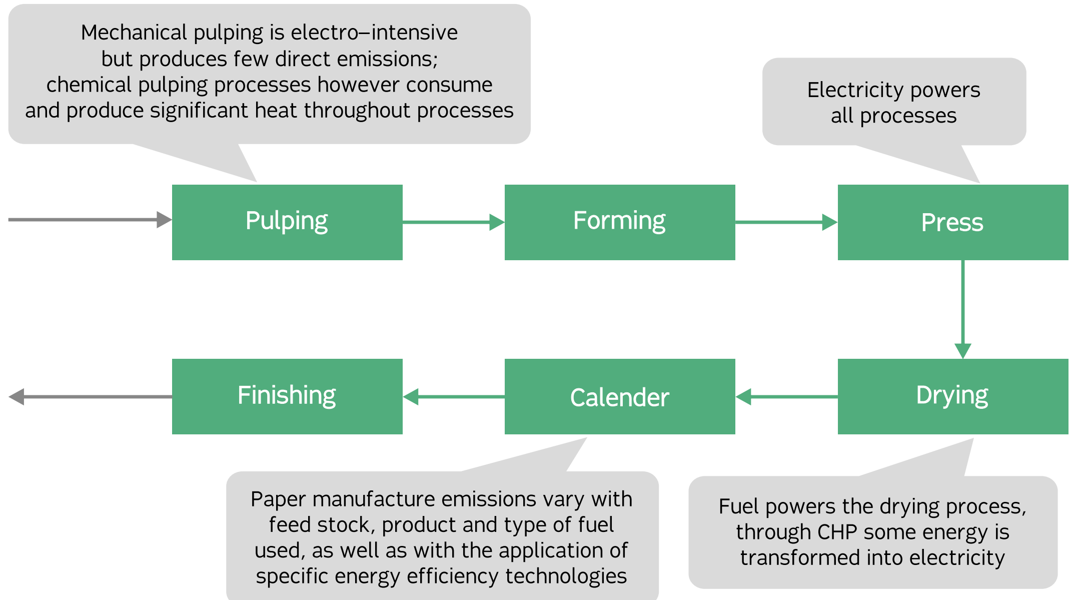
(38) All data from the sources summarised in Table 16 unless indicated

Products and processes

The six basic steps of paper production are capital and energy intensive. To produce paper, pulp is mixed with water to produce a pulp slurry, which is then sprayed onto a screen. This web of slurry is subsequently pressed at high speed between large rolls that squeeze out the water. The pressed sheet is passed to heated cylinders for drying, after which the paper passes through the 'calender', a series of high pressure rollers to provide finish and ensure uniform consistency. The paper is rolled up at the end of the machine and later re-rolled into smaller reels ready for shipping.

The most emissions intensive step in paper production is the drying process. Emissions from paper production are dependent on feedstock, product and fuel used as well as energy-efficiency processes in use. The single most emissions intensive step in production is the drying process, which uses energy to produce pressurised steam used for drying in the cylinders and is a source of high indirect emissions. Figure 26 illustrates the key production process of pulp and paper.

Figure 26. There are 6 key processes involved in the manufacture of paper and paper products



Source: Vivid Economics

Cost pass-through capacity

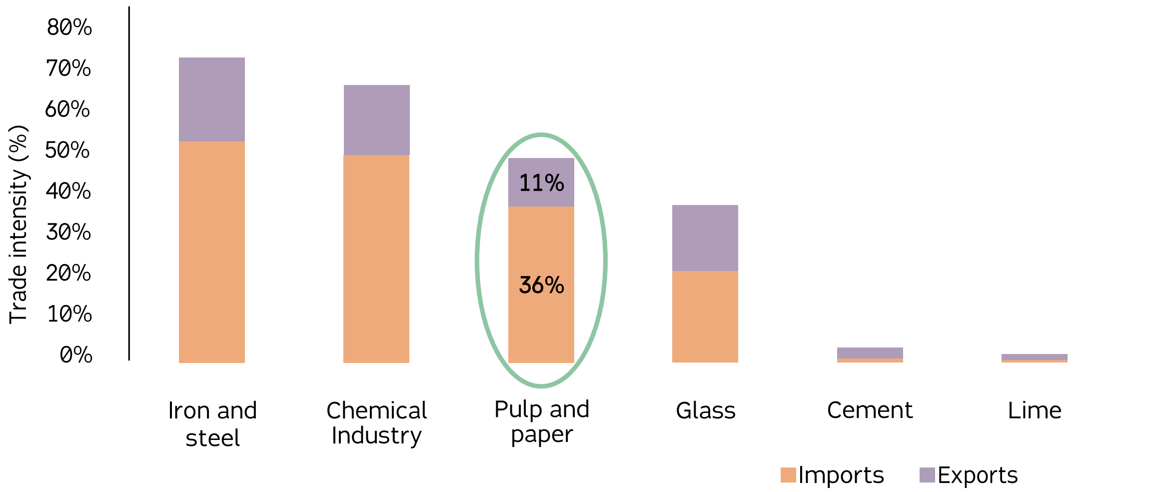
The sector's growth attracted investments and increased capacity in recent years. For example, Grupo Condi alone, one of the biggest domestic paper producers, invested USD300m in a new paper mill to accommodate the rising demand for paper and packaging[39]. Despite increased investment and capacity, the expansion has not kept pace with the fast growing demand, partly driven by the manufacturing sector[40]. This suggests that competition is not fierce, leaving some capacity to pass through costs.

The pulp and paper sector exhibits high trade intensity, mainly due to import competition. Average trade intensity between 2014 and 2016 was 47%. Mexico exported USD2bn (MXN38bn) and imported USD6bn (MXN122bn) in 2016, leading to a trade deficit of USD4bn. Figure 27 plots trade intensities for the six analysed sectors.

(39) Papnews (2017). Grupo Gondi to invest $300 million to build new paper mill in Mexico. https://www.papnews.com/grupo-gondi-invest-300-million-build-new-paper-mill-mexico/

(40) RISI (2016). Mexico on track to become second-largest paper packaging market in Americas. https://www.risiinfo.com/press-release/mexico-track-become-second-largest-paper-packaging-market-americas/

Figure 27. Pulp and paper manifests high trade exposure, mainly due to a high dependence on imports



Note: Trade intensity is calculated as (trade volume)/(domestic market size)
Source: Vivid Economics

The US, a country without a federal carbon price, accounts for almost three quarters of both imports and exports. It constituted 72% of imports and 74% of exports in the pulp and paper sector in 2016. The lack of carbon pricing in the sector's major trading partner increases the risk of carbon leakage. All other countries in both the import and export market account for less than 5%. Table 26 depicts the top five import and export countries.

Table 26. Key import and export countries for the pulp and paper sector in 2016

Rank	Imports (% share of total in brackets)	Exports (% share of total in brackets)
1	USA (72%)	USA (74%)
2	China (4%)	Guatemala (3%)
3	Brazil (4%)	Costa Rica (3%)
4	Canada (4%)	Panama (2%)
5	Germany (2%)	Nicaragua (2%)

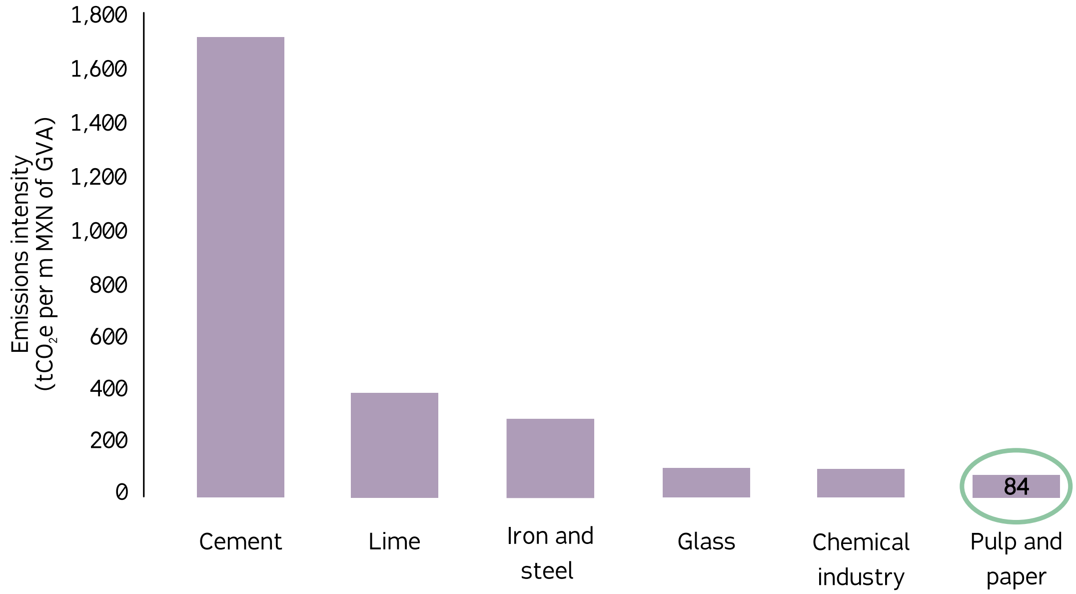
Source: Vivid Economics

Carbon cost exposure

The pulp and paper sector exhibits relatively low emissions intensity compared to other sectors, the lowest of all analysed sectors. Average emissions intensity as tons of CO_2-equivalent emissions per million MXN of Gross Value Added (GVA) was 84 (1,311 tCO_2/USDm) between 2014 and 2016. California exhibits an emissions intensity of 3,111 tCO_2/USDm for paperboard manufacturing and 1,663 tCO_2/USDm for paper manufacturing[41]. This suggests that the Mexican pulp and paper sector has already materialised some abatement option in the past, leading to increased carbon leakage risk. 72% of total emissions were direct emissions while the remainder stemmed from electricity consumption. The sector increased its emissions intensity by 15% between 2014 and 2016. Figure 28 displays emissions intensity for all six sectors in 2016.

(41) ARB (2010). Appendix K Leakage Analysis. https://www.arb.ca.gov/regact/2010/capandtrade10/capv4appk.pdf

Figure 28. Pulp and paper exhibits relatively low emissions intensity



Source: Vivid Economics

There are three further abatement opportunities in the production of paper:

1. **Increased use of combined heat and power (CHP):** Cogeneration of heat and power uses a single fuel and facility to produce both electricity and heat (CHP), resulting in higher fuel efficiency. The production of paper requires heat for drying using both boilers and CHP for this process. Mill CHP is normally designed to cover heat use with power demand balanced with grid import and export. Widespread use of CHP adds to security of supply and (when compared with grid displaced electricity) reduces total emissions (although it may add to emissions measured on-site). Use of CHP can continue growing through capacity increases or newbuilds but may be affected by natural gas procurement specifications or other economic factors.

2. **Increased production efficiencies:** Increased production efficiencies through mill modernisation can reduce emissions. New technologies and new process equipment can be an abatement option. These include: advance vacuum pumps; advanced presses; and modernisation of the paper machine hood. Increases in the heat transfer capacity of the paper machine and isolation of the paper mill could yield further efficiency improvements. Importantly, the capacity of a paper mill depends both on the speed and the width of the paper machine. Only the speed of the machine can be increased through modernisation, and the width should remain unchanged for technical reasons. The most efficient measure, therefore, is to design new paper mills with optimum capacity and advanced technology.

3. **Transitioning to alternative fuels like biomass or natural gas:** Biomass and natural gas could serve as lower emissions-intensive fuels. As on-site co-generation of steam and electricity is commonplace, switching to natural gas could be a first, economically feasible step to reducing plant emissions intensities. Government investment incentives to install anaerobic wastewater treatment plants could facilitate the transition. Beyond this, biomass represents a further available fuel source: 54% of the EU paper industry's energy consumption is biomass based[42]. However, transition to widespread use of biomass in Mexico might be inhibited by low existing supply and high operation costs.

Carbon leakage risk assessment

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the pulp and paper sector produced the following results:

1. California metric: pulp and paper identified to exhibit 'high' leakage risk based on high trade intensity; EU ETS Phase III metric: pulp and paper identified based trade intensity;
2. EU ETS Phase IV metric: pulp and paper identified.

Table 27. International metrics clearly identify the pulp and paper sector at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

The sensitivity analysis changes the assessment of the pulp and paper as at high risk. An exclusion of indirect emissions leaves the sector only at medium risk, suggesting that if cost pass-through in the power sector is low pulp and paper's carbon leakage risk is less severe. The other sensitivity tests do not alter the initial assessment.

There are several factors additionally affecting the carbon leakage risk:

- the high trade exposure, especially to jurisdictions without carbon pricing, suggests that cost pass-through may be limited. Additionally, the comparison of emissions intensity with other jurisdictions indicates that some abatement options have already been utilised, limiting the potential for future abatement. This could aggravate carbon leakage risk.
- Mexican firms increased capacity and investment to attempt the accommodation of rapid growth of demand in recent years. It indicates that competition is currently not fierce and there may be some potential for cost pass-through. This could reduce carbon leakage risk.

(42) Confederation of European Paper Industries (CEPI). (2012). Resource efficiency: cascading use of raw material.

6. Chemical industry

Sector Overview

Economic overview

The chemical industry contributes significantly to the Mexican economy and employment. It produced MXN740bn worth of goods in 2016 and employed roughly 160,000 people[43]. The sector's production declined by 11% in real terms between 2010 and 2016, despite the growth of the whole economy in the same period. Employment has been declining as well, but with 4% at a slower pace with in the same period. Nevertheless, the sector remains important to the Mexican economy, contributing 2.1% to the country's GDP in 2016.

Products and processes

The Mexican chemicals sector produces a wide range of products, divisible into three main categories: basic industrial chemicals, speciality chemicals and consumer chemicals. This classification is dependent on the product's intended end use. Basic industrial chemicals include petrochemicals, fertilizers and other chemicals used in manufacturing; speciality chemicals include paints, dyes and pigments, glues and industrial gases and, finally, consumer chemicals include cleaning and personal care products. In Mexico, petrochemicals represent 39% of chemical production organised in the industry association ANIQ. The second biggest sub-sector is inorganics (19%), followed by industrial gases (16%), synthetic rubber (16%) and fertilisers (8%)[44].

Cost pass-through capacity

Competitive dynamics are different in different subsectors of the chemical industry. In petrochemicals, the largest subsector, the market is very concentrated. The state-owned Petróleos Mexicanos (PEMEX) is dominating the market, selling almost twice as many tons of petrochemicals as the whole private sector in 2015[45].

Studies on the EU ETS suggest high cost past-through in some chemical sub-sector in other jurisdictions. A high cost pass-through capacity is one of the main factors determining the potential impact of a carbon price on firms' competitiveness. An ex post analysis of the impacts of the EU ETS suggests that cost pass-through for the main sub-sector petrochemicals as well as for fertiliser could be above 100%[46].

Trade intensity is high in the sector, mainly dominated by imports. Average trade intensity between 2014 and 2016 was 64%, mainly driven by imports. In 2016, Mexico exported USD14bn (MXN271bn) and imported USD41bn (MXN821bn), leading to a trade deficit of USD27bn. As products within the chemical industry are diverse, trade intensity can vary substantially between sectors. Figure 29 plots trade intensities for the six analysed sectors.

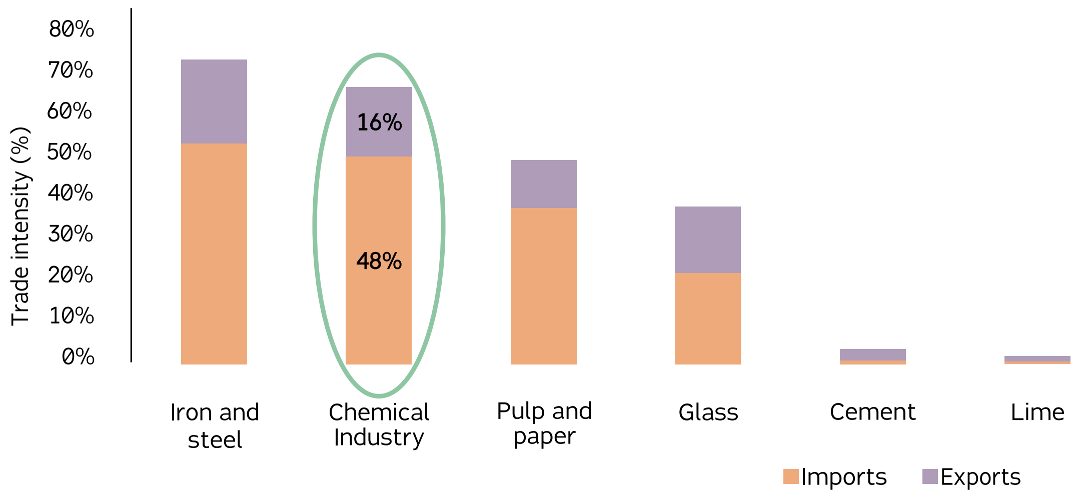
(43) All data from the sources summarised in Table 16 unless indicated.

(44) ANIQ (2017). Anuario Estadístico de la Industria Química Mexicana. http://www.aniq.org.mx/anuario/2017/index.html

(45) Global Business Reports (2015). Mexico Chemicals. https://www.gbreports.com/wp-content/uploads/2015/05/Mexico_Chemicals2015_IE.pdf

(46) CE Delft and Oeko-Institut (2015). Ex-post investigation of cost pass-through in the EU ETS. https://ec.europa.eu/clima/sites/clima/files/ets/revision/docs/cost_pass_through_en.pdf

Figure 29. The chemical industry manifests high trade exposure dominated by a high share of imports



Note: Trade intensity is calculated as (trade volume)/(domestic market size)
Source: Vivid Economics

The US is the main trading partner for the chemical industry; its lack of federal carbon pricing increases the risk of carbon leakage. However, the significance is less pronounced than in other sectors. The country accounted for almost 60% of imports and approximately half of exports in 2016, its significance is less pronounced than in other sectors. While for imports, most remaining competing countries have at least some regional or national carbon pricing scheme in place, the main export destinations do not have federal carbon pricing in place. Table 28 depicts the top five import and export countries.

Table 28. Key import and export countries for the chemical industry in 2016

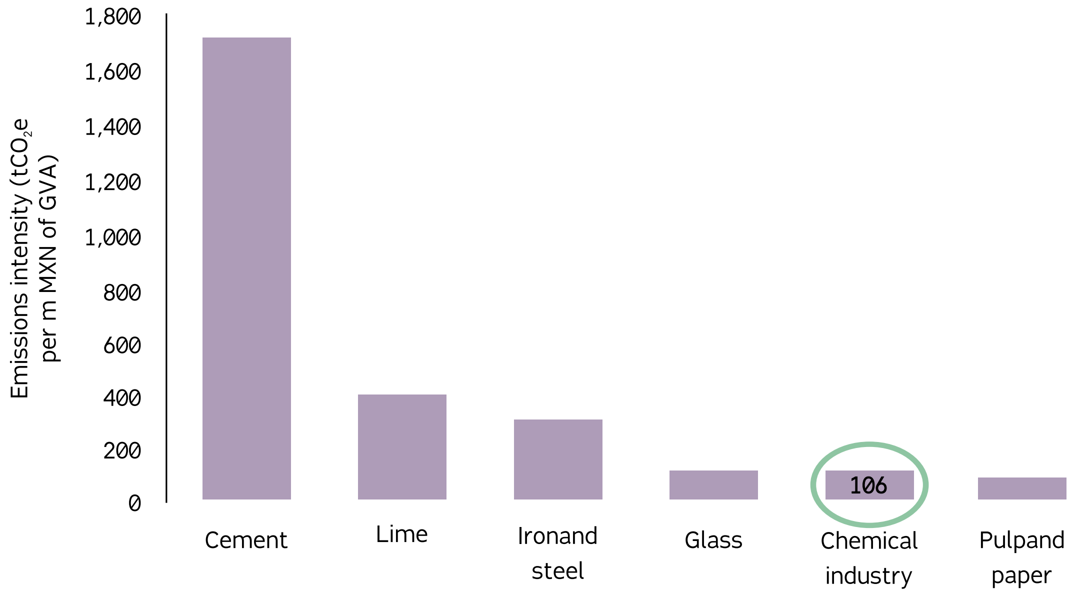
Rank	Imports (% share of total in brackets)	Exports (% share of total in brackets)
1	USA (58%)	USA (49%)
2	China (7%)	Brazil (5%)
3	Germany (5%)	Columbia (4%)
4	Ireland (3%)	Guatemala (3%)
5	Canada (3%)	Belgium (3%)

Source: Vivid Economics

Carbon cost exposure

The chemical industry exhibits relatively low emissions intensity on average, but figures might vary significantly between subsectors. Average emissions intensity as tons of CO_2-equivalent emissions per million MXN of Gross Value Added (GVA) was 106 (1,654 tCO_2/USDm) between 2014 and 2016. 94%, almost all, of total emissions were direct emissions while the remainder stemmed from electricity consumption. The sector increased its emissions intensity by 32% between 2014 and 2016, although this could also be due to changes in composition of the industry. Figure 30 displays emissions intensity for all six sectors in 2016.

Figure 30. The chemical industry exhibits relatively low emissions intensity on average



Source: Vivid Economics

Carbon leakage risk assessment

The selection methodology makes use of three key international carbon leakage identification metrics. Analysis of the chemical industry produced the following results:

1. California metric: chemical industry identified to exhibit 'high' leakage risk based on high trade intensity.
2. EU ETS Phase III metric: chemical industry identified based trade intensity;
3. EU ETS Phase IV metric: chemical industry identified.

Table 29. International clearly identify the chemical industry at risk

	California			EU ETS Phase III				EU ETS Phase IV
Metric	**Trade intensity**	**Emissions intensity**	**Level of Risk**	**Trade intensity**	**Cost Increase**	**Joint Metric**	**Identified**	**Identified**
Initial Assessment	High	Medium	High	Yes	No	Yes	Yes	Yes

Source: Vivid Economics

Sensitivity analyses do not change the assessment of the chemical industry as at risk. Changes in assumptions on carbon price, exclusion of trade with jurisdictions with carbon pricing in place, and indirect emissions do not change the risk assessment.

There are several factors additionally affecting the carbon leakage risk:

- the high trade exposure, especially to jurisdictions without carbon pricing suggests that the sector would not be able to substantially pass through carbon costs. This could aggravate carbon leakage risk.
- the high market concentration in the petrochemical sub-sector and tentative evidence from other jurisdictions suggest that cost pass-through capacity may be high. This could reduce carbon leakage risk.
- the large diversity in products and product processes hamper the carbon leakage assessment for the whole sector. More granular data must be collected and analysed to conclude on carbon leakage in the chemical industry.

Appendix C: Economy-Wide Model - methodology

Overview of global-Vivid Economy-Wide model

The Global Vivid Economy-Wide (GViEW) model is an economy-wide comparative static computable general equilibrium model capable of analysing trade flows across multiple regions. It is economy-wide in the sense that it models relatively large parts of the economy such as sectors as single units based on patterns in their aggregate behaviour. It sets up a coherent framework to simulate the functioning of a market economy by examining the production and trade relationships between different sectors and regions. It is precisely these intersectoral relationships which allow CGE models to estimate the indirect impact of policies across the global economy. The model encompasses multiple specified regions and can assess trade flows between regions with diverging climate policies. It models energy production, carbon dioxide emissions, trade and investment as well as interactions between these. In the Mexico calibration, GViEW distinguishes between 21 sectors of the economy and reports the key sectors at risk of carbon leakage: non-metallic minerals, ferrous metals, non-ferrous metals and chemicals and plastics.

GViEW uses integrated Social Accounting Matrices (SAMs) from the Global Trade Analysis Project (GTAP) database to model regions and simulate trade flows. The latest available base year from the GTAP database is 2011, necessitating calibration of the model to the most recent data before simulating future years. The model requires emissions and GDP estimates as inputs to estimate the future pace and path of the economy.

GViEW facilitates aggregated sectoral carbon leakage estimation for key industrial subsectors at specified points in time. GViEW excels at assessing macroeconomic effects as it can capture general equilibrium effects within and across economic regions. Consequently, it is well suited to evaluate the impact of different climate policies across trade partners. GViEW estimates carbon leakage by analysing the change in trade flows following the introduction of a climate policy compared to a 'business-as-usual' scenario, thereby highlighting carbon leakage risks. The model is also particularly adept at assessing the linkages, modelled by the circular flow of income, within and across economic regions.

Model inputs

GDP

In GViEW, GDP forecasts inform the initial pace of economic expansion prior to policy shocks. In the Mexico calibration, the GDP forecast to 2021 is the average of growth rate estimates and projections between 2011-2019 from the OECD. For the European Union, 2011-2019 GDP estimates and projections are from Eurostat. GDP forecasts are inputted into the model for each region as listed in Table 30.

Table 30. GDP growth forecast by region

Country	Long run GDP forecast
Mexico	2.7%
Canada	2.1%
China	7.2%
United States	2.2%
European Union	1.6%
Rest of World	3.5%

Note: OECD forecast used for all regions, except the EU where Eurostat's forecast is used
Source: (OECD 2018b), (World Resources Institute 2018a) and (Eurostat 2018)

Emissions pathways

GViEW optimises economic activity within and across regions with respect to a specified emissions constraint at the regional level. The model can cover multiple types of greenhouse gases (GHGs). In the Mexico calibration, the ETS covers CO_2 emissions from combustion and CO_2 process emissions. Table 31 lists the gases included in the Mexico calibration.

Table 31. Emissions covered for economy-wide model

Coverage	Comment
CO_2 emissions from combustion	The model includes CO_2 emissions from fuel combustion and process emissions in industry.
CO_2 process emissions	Non-CO_2 greenhouse gases are beyond the scope of this study.

Source: Vivid Economics

The emissions cap for each region is the estimate of carbon dioxide emissions in 2021 that place the region on track to meet its 2030 NDC target. The model is comparative static and does not consider the time path between the 2011 base year and 2021, that is, it does not estimate economy outcomes in intermediate years. For illustrative purposes, the divergences in emissions pathways between policy scenarios and BAU can be thought to occur in 2020, before the introduction of the ETS in each region.

The 2021 emissions cap imposed in the model assumes a linear path of emissions in each region in 2021 based on a linear projection of emissions between 2011 and 2030. The initial emissions data is from the 2011 GTAP database and the 2030 CO_2 emissions cap estimates (under a Paris scenario) are sourced from the State and Trends of Carbon Pricing (STCP) 2016 (World Bank 2016). The 2011 emissions base year is needed to align data with the GTAP database 2011 base year, which is necessary for proper functioning of the model.

Mexico 2021 conditional and unconditional NDC emissions caps are the quantity of CO_2 emissions (from combustion and process) as part of the total CO_2 equivalent (CO_2e) emissions cap. The CO_2e cap is Mexico's NDC target in 2021 as necessary to be on track to meet Mexico's conditional and unconditional 2030 NDC targets. The ratio of CO_2 to CO_2e emissions is determined by comparing World Resources Institute CO_2 only emissions estimates for 2013 and STCP CO_2 only emissions projections for 2030 against Mexico's NDC emissions pathways (World Resources Institute 2018b)(World Bank 2016)(UNFCCC 2015b). The CO_2 to CO_2e ratio informs the linear estimate of the necessary emissions cap required for Mexico be on track to meet either its conditional or unconditional NDC.

Table 32 summarises the CO_2 emissions pathways under a Paris scenario and lists the 2021 CO_2 emissions projections by region.

Table 32. CO_2 combustion and process emissions by region ($MtCO_2$)

Country	2011 (GTAP)	2030 (STCP)	2021 projection
Mexico unconditional	454	424	501
Mexico conditional	454	347	492
Canada	545	413	475
China	9,511	13,484	11,602
United States	5,257	4,117	4,657
European Union	3,562	2,876	3,201
Rest of world	14,036	15,054	14,572

Source: Vivid Economics based on the State and Trends of Carbon Pricing 2016 (World Bank 2016)

Modelling set up

Sectors

Given the six sectors identified as being at risk of carbon leakage in the sectoral analysis, the economy-wide analysis considers non-metallic minerals, ferrous metals, non-ferrous metals and chemicals and plastics. These sectors are the aggregations available from the GTAP database. The GTAP database includes social accounting matrices (SAMs) that capture the flow of inputs between sectors. SAMs are very time intensive to construct, limiting GVIEW to the sectoral granularity available from the GTAP database. Consequently, key sectors at risk of carbon leakage, such as cement, lime and glass are included in the aggregate non-metallic minerals sector. In the GTAP database, the paper and pulp sector is grouped into 'other manufacturing' and disaggregation is difficult, therefore sectoral analysis is particularly important for this sector. The model also covers electricity. However, electricity is not substantially traded and is therefore less at risk of carbon leakage or loss of competitiveness due to its relatively low trade intensity, so it is not reported[47].

Table 33 presents the key sector aggregations in the Mexico calibration.

Table 33. Key sectors for economy-wide model

GTAP Sector	Description
Non-metallic minerals ('minerals')	***Cement***, *plaster*, ***lime***, *gravel, concrete*, ***glass*** *and ceramics*
Ferrous metals	***Iron and steel***, *basic production and casting*
Non-ferrous metals	*Production and casting of copper, aluminium, zinc, lead, gold, and silver*
Chemicals and plastics	***Basic chemicals, other chemical products***, *rubber and* ***plastic products***

Note: Boldened sectors are covered in the sectoral analysis
Source: Vivid Economics

Regions

The countries directly covered by the GViEW model represent more than 90% of Mexican export destinations by value. The US (81%) is the main export destination for Mexico followed by the EU (5.4%) (The Observatory of Economic Complexity 2018b). China is included because China is a top competitor and import destination. Canada is also included to ensure full representation of NAFTA members. Table 34 lists the regional aggregations in the Mexico calibration and each region's trade relationship with Mexico.

(47) Although electricity has a low trade intensity at the national level, the electricity sector in certain Mexican states, such as Baja California, may have a higher trade intensity due to high interconnector capacity with the United States – but in the case of Baja California the interconnection is with a jurisdiction with existing carbon pricing (California Cap and Trade).

Table 34. Regions for the economy-wide model

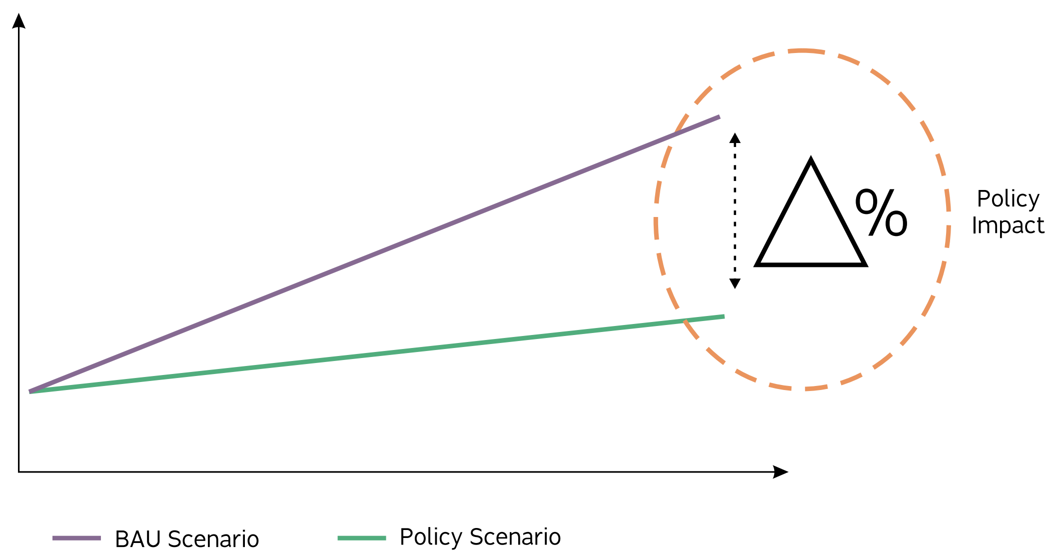
Category	Aggregation	Mexican export destinations	Mexican import origins
Regions	Mexico	-	-
	USA	81.0%	47.0%
	Canada	2.8%	2.5%
	European Union	5.4%	12.0%
	China	1.4%	18.0%
	Rest of world	9.4%	20.5%

Source: Vivid Economics and trade percentages from (The Observatory of Economic Complexity 2018b)

BAU scenario

GViEW evaluates the impact of a policy change relative to a business-as-usual scenario. Initial calibration sets out what is the most likely 'business as usual' or 'baseline' outcome that excludes climate policy interventions. The BAU scenario assumes the growth rate of specific GDP growth for each region. The difference between the BAU scenario and the policy scenario shows the impact of the introduction and implementation of the policy. Figure 31 depicts how to interpret the difference between the BAU and policy scenario. The BAU scenario is important as it allows for a comparison of the effects of policy scenarios compared to business-as-usual.

Figure 31. The difference between the BAU and policy scenario shows the policy impact



Note : The gap between the BAU and policy scenario can be thought of the policy impact. The policy impact is often expressed as a percentage change between the BAU and policy scenario, signified by a delta percentage symbol in the dashed circular region in the figure above.

Source: Vivid Economics

Policy scenarios

The first set of scenarios are based on policy changes within Mexico. For Mexico, the ETS allocation method is calibrated to grandfathering. The ETS covers the four key sectors and electricity to achieve their proportionate share of the NDC path in 2021.

- In the **unconditional scenario**, Mexico is on track to achieve its 22% below BAU unconditional emissions target.
- In the **conditional scenario** Mexico is on track to increase its emissions reductions and achieve its 36% below BAU conditional target.

The second set of scenarios are based on international climate policy changes. To date, all countries have signed the Paris Agreement. However, the current US administration began the process of withdrawing from this agreement in 2017. While this process will take several years and might be subject to political change, it is a relevant factor for Mexico. This produces two scenarios, one where Paris succeeds and one where the US drops out of Paris.

- In **All in Paris** ('Paris') all countries are on track to achieve their unconditional 2030 NDC targets.
- In **US drops out** ('US out'): the US leave Paris and is not on track to achieve its 2030 NDC target, but all other countries are.

In scenarios where the US drops out of Paris the model continues to consider the impact of California's ETS. California has substantial trade with Mexico and an ETS in place with an announced minimum carbon price for 2021[48]. In the policy scenarios where the US is out of Paris, the US carbon price is weighted to account for California's announced ETS auction reserve (minimum carbon) price in 2021 ($15.42/tonne of CO_2) (California Air Resources Board 2018). The weighting applied to California's minimum carbon price is the percentage of California's trade with Mexico divided by total US trade with Mexico, determined to be 13.1% in 2017 (California exports plus imports to and from Mexico divided by US exports plus imports to and from Mexico) (United States Census Bureau 2018). Table 35 summarises the possible policy scenarios.

Table 35. Mexico modelling policy scenarios

		International Ambition	
		US Drops Out	All in Paris
Mexico Ambition	**Unconditional**	Main Scenario	Paris Agreement Success
	Conditional	Increased Ambition	Maximum Ambition

Note: The maximum ambition scenario is not presented in this report as it is judged the least likely scenario given policy announcements.
Source: Vivid Economics

(48) A collection of north-eastern US states has also implemented an ETS known as the Regional Greenhouse Gas Initiative (RGGI). The model does not consider the impact of the RGGI ETS due to the relatively low trade volume between Mexico and this group of US States compared to Mexico-California trade.

Modelling assumptions

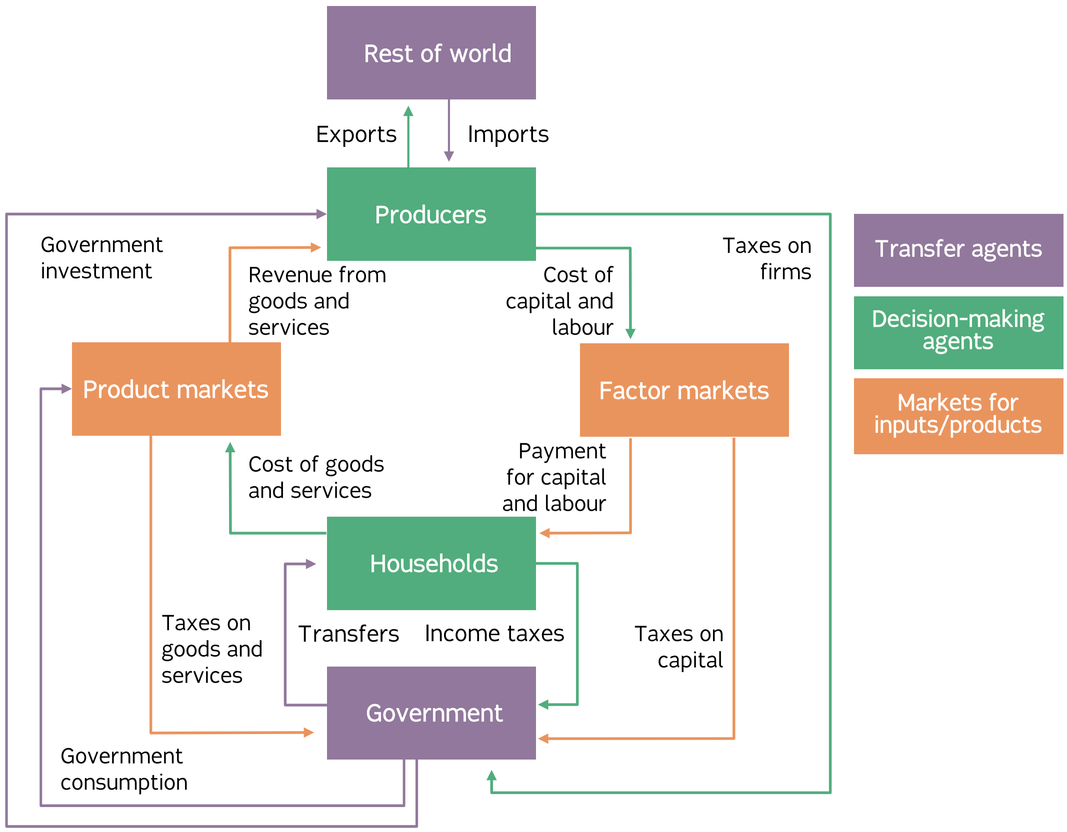
The GViEW model has key attributes and imposes multiple assumptions in order to model the economy of Mexico. In each region and sector, there is a representative firm that produces output by hiring primary factors and purchasing intermediate inputs from other firms. There is also a representative agent in each region that derives income from selling factor services and an exogenous net international transfer that reflects the current account balance. The government sector is not explicitly modelled, but taxes and subsidies on transactions are represented, and government purchases are included in household consumption in each region. Net fiscal deficits and, where applicable, revenue from the sale of emissions permits are passed to consumers as (implicit) lump sum transfers. Although the model is static, investment is included as a proxy for future consumption and is a fixed proportion of expenditure by each regional household.

Figure 32 presents the 'circular flow of income', that is, the interactions between the four different types of agents featured in GViEW:

- **households:** households maximise their satisfaction by choosing which goods and services to purchase and consume. They earn money by working for producers as well as renting capital, such as machinery, to them;
- **producers:** producers maximise their profit by choosing how much goods and services to produce and sell to households and other producers. Producers create goods and services by employing workers from households and purchasing inputs from other producers;
- **the government:** the government collects tax revenue and spends it on consumption, investment and transfers to households; and
- **trade partners:** GViEW models the rest of the world as one aggregated into five blocs discussed in Appendix C with whom Mexico trades.

Economic decision-making is the outcome of the choices made by households and producers. Both these agents have an explicit goal insofar as households want to maximise their satisfaction and producers want to maximise their profit. Households make this choice based on their preferences, which define how much satisfaction they get from different combinations of goods and services. Producers make this choice based on their production possibilities, which define how much output they can produce from different combinations of inputs. This means that both sets of agents have a set of rules which, for every possible version of the economy, defines what choice they should make. In addition, both households and producers act rationally, that is, they never deviate from their set of rules. While the government does not have an explicit maximisation goal, it can be seen as acting in the interest of households.

Figure 32. The interaction of four agents across two sets of markets define the dynamics of GViEW



Note: The diagram aggregates producers as a whole though producers also purchase products from other producers as inputs. Products refers to goods and services.
Source: Vivid Economics

When households and producers make these decisions, they must take into account three central assumptions about the economy:

- **markets clear:** households consume all the output producers generate and producers use all households' available labour and capital. In other words, the demand for every product and factor is equal to the supply of that product or factor;

- **zero profit:** all markets are competitive and there are no barriers to entry for new producers. When a producer is making a positive profit in a specific market, other producers will be incentivised to enter that market to also earn profit. This will increase the total supply of the product and cause the market price to fall. This process will continue until producers' revenue is equal to their costs and thus, they make zero profit;

- **income balance:** households spend all their money on goods and services or invest it. Money is never left unused.

All households are identical and all producers within a sector are identical. In line with most CGE models, GViEW does not represent differences in either preferences or endowments of labour and capital across households. Similarly, it does not represent differences in the production possibilities of different producers within the same sector. Instead, the characteristics of households and producers in each sector are chosen to best reflect the group as a whole.

In its calibration for Mexico, GViEW simplifies the dynamics of money markets. GViEW assumes an exogenous fixed money supply, that is, financial institutions cannot create additional money. As a result, any increase in investment must be met with either an equivalent increase in savings or a reduction in investment elsewhere.

GViEW solves each period recursively to 2021. Households and producers make their optimal choices in the first year based on the assumptions and policies active in that year. This determines how much households invest and in which sectors. This in turn determines the allocation of capital and land across sectors in the following year. Households and producers then make their optimal choices for the following year based on these allocations and the assumptions and policies that are active in that year. This process continues until results are calculated for all years to 2021.

GViEW is calibrated using data from version 9 of the Global Trade Analysis Project (GTAP) database (Aguiar, Narayanan, and McDougall. 2016). The GTAP 9 database provides granular bilateral trade information, including transport and trade protection linkages across 57 commodity-sectors such as wheat, forestry, coal, ferrous metals and insurance[(49)]. GViEW also utilises the GTAP Power database to further disaggregate the electricity generation sector into individual generation technologies. In addition to production and trade data, the GTAP 9 database includes carbon dioxide emissions by fuel, user and region from the International Energy Agency (IEA).

GViEW uses elasticities of substitution to capture the consumption and production behaviour of households and aggregate production sectors respectively. These elasticities define how willing households are to switch between different goods and services and how willing producers within a sector are to switch between different production inputs. GViEW uses Armington trade substitution elasticities to capture trade behaviour between regions, where internationally traded products are assumed to be differentiated by country of origin. This 'Armington assumption' generates more realistic shifts in trade to price changes than products not differentiated by origin. Elasticities can be interpreted as price sensitivity insofar as a higher elasticity of substitution indicates that households or producers will change what they consume more in response to a change in relative input prices. In its calibration for Mexico, GViEW mostly takes these parameters from the MIT Economic Projection and Policy Analysis (EPPA) model version 5 (Chen et al. 2017).

Additional results

The carbon prices listed in Table 36 are the implicit carbon prices required across Mexico's economy to achieve the NDC target. They are the carbon prices for the four key sectors and the electricity sector to achieve their proportionate share of the NDC path in 2021. These prices are implicit in the sense that they capture other policies in place and are not necessarily indicative of the actual prices that would be observed in the ETS.

Table 36. Estimated carbon prices in 2021

Scenario	Carbon price (USD/tCO_2)
Unconditional target and US out of Paris Agreement	18
Unconditional target and US in Paris Agreement	21

Source: Vivid Economics

(49) A full list of GTAP 9 sectors is available at https://www.gtap.agecon.purdue.edu/databases/contribute/detailedsector.asp. For modelling and reporting purposes, individual commodity-sectors are aggregated to form broader sector categories.

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Editorial design and creative direction by:
Edgar Javier González Castillo
and La Estación de Servicio.

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Friedrich-Ebert-Alle 36+40
53113 Bonn, Deutschland
T +49 228 44 60-0
F +49 228 44 60-17 66

Dag Hammarskjöld-Weg 1-5
65760 Eschborn, Deutschland
T +49 61 96 79 0
F +49 61 96 79 11 15
E info@giz.de
I www.giz.de

Project:
Preparation of an Emissions Trading
System in Mexico (SiCEM)

Av. Insurgentes Sur No. 826, PH
03100 Col. del Valle, CDMX México
E comercio.emisiones-MX@giz.de
E emissions.trading-MX@giz.de

Secretaría de Medio Ambiente y Recursos
Naturales (SEMARNAT)
Avenida Ejército Nacional 223, piso 19
Del. Miguel Hidalgo, Col. Anáhuac
11320 Ciudad de México
E mexico.ets@semarnat.gob.mx