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Flying toward sustainability: A meta-analysis of consumer willingness to pay for emission reduction in air travel

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Summary

Air travel contributes a substantial share of global greenhouse gas emissions and is projected to rise further in the coming years. Given the urgency of climate change mitigation, reducing or offsetting emissions within the aviation sector is imperative. To successfully design and implement emission reduction projects, airlines and policymakers must understand consumer preferences and willingness to pay (WTP) for sustainability in air travel. Several studies have been conducted in recent years with this objective; however, they encompass diverse contexts and circumstances, resulting in considerable variation in the reported WTP values and no clear way to explain the differences. Therefore, this thesis undertakes a meta-analysis to establish a comprehensive understanding by standardising the findings and identifying key factors that influence WTP. The meta-analysis employs weighted least squares regression models and includes two sampling methods, drawing from the results of 31 primary studies. The findings reveal that consumer WTP can be up to 160% higher for a credible offsetting scheme compared to one lacking credibility. Additionally, the results indicate that framing the offset as “per flight” rather than “per tonne CO_2” also increases WTP, although there is no discernible correlation of WTP with the offset being voluntary or mandatory. Higher income, more education, and pro-environmental attitudes were all found to increase WTP, while age and gender do not appear to have a consistent influence. The results presented in this thesis yield significant insights that can be applied to the design of effective carbon offsetting schemes, thereby enhancing the sustainability of aviation in the future.

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1. Introduction

Climate change mitigation is among the top priorities worldwide. Air travel alone contributes a significant proportion of global greenhouse gas (GHG) emissions, with current estimates at 2% and projected to increase up to 25% of the global carbon budget by 2050 (Graver et al., 2019; ICAO, 2019). Therefore, it is imperative for the aviation industry to adapt and reduce its emissions. Three options exist for reducing air travel emissions: reducing the frequency of flying; utilising advanced technologies to minimise emissions per flight; or offsetting emissions through initiatives like reforestation projects. However, to achieve any of these measures, consumers must make a trade-off, either by adjusting travel plans or by making financial contributions to support technological advancements or offsetting projects. Consequently, understanding the motivating factors behind consumer trade-offs, the value they assign to emission reduction, and the influencing factors becomes critical for the successful implementation of such measures.

Considering the importance of GHG mitigation in the aviation industry, substantial research has been conducted to investigate consumers' willingness to pay (WTP) for offsetting air travel emissions. However, the previous research is not being used to its full potential since the contexts being tested are diverse and inconsistent, resulting in incomparable findings. Therefore, this thesis aims to provide a comprehensive analysis of the various findings to establish a unified understanding of WTP and uncover practical insights that can be utilised by policymakers and airlines to encourage air travellers in emission reduction efforts. With this objective, the following research questions will be addressed:

1. *How much are consumers willing to pay to reduce emissions in air travel?*
2. *What factors influence a consumer's WTP for reduced emissions in air travel?*
3. *What accounts for the variation in WTP observed across different studies?*

To answer these research questions, a meta-analysis is conducted, synthesising the findings from all prior studies that have examined consumer WTP in mitigating air travel emissions. The WTP estimates from each study are standardised and converted into a common measure, specifically WTP per tonne of CO_2 (tCO_2) in 2021 US dollars (USD), which serves as the dependent variable in a regression analysis. The meta-regression incorporates moderator variables, facilitating hypothesis testing to identify the influential factors and discover other relationships with WTP values. It is important to note that this thesis does involve the collection of new WTP estimates. Instead, it relies on existing studies that have reported WTP estimates and associated attributes, ensuring a robust and comprehensive dataset for analysis.

The remainder of the thesis is structured as follows: Section 2 provides background information to understand the context surrounding consumer WTP for air travel emission mitigation. Section 3 analyses relevant theories to identify factors that may influence an individual's WTP and the reported values. Through this analysis, hypotheses are formulated to guide the subsequent research. Section 4 describes the methodological approach used to conduct the meta-analysis, including primary study selection criteria, data collection, and the techniques employed to standardise and analyse the WTP estimates. Section 5 presents the results of the meta-analysis, encompassing a meta-regression, a sensitivity analysis, and a qualitative review of each primary study. Section 6 discusses the findings in depth, providing interpretations and applications. Lastly, Section 7 presents concluding remarks.

2. Background

This section establishes the foundation for understanding the context in which consumer WTP for air travel emission reduction operates by examining the environmental impact of aviation, explaining the mechanisms of carbon offsetting, and providing an overview of the current state of research in this field.

2.1 Environmental impact of aviation

Climate change is among the most important and urgent issues worldwide and has prompted many countries and international organisations to enact targets for carbon reductions, such as the Paris Agreement to reach net-zero emissions before 2050 (Jones, 2023; World Travel and Tourism Council, 2021). While over 100 countries have committed to carbon neutrality commitments, a gap persists between individual country targets and the goals outlined in the Paris Agreement (Wu et al., 2022).

The aviation industry is responsible for a substantial portion of global GHG emissions, contributing approximately 2% of global man-made carbon emissions (ICAO, 2019). Despite a significant reduction in air travel in 2020 due to the Covid-19 pandemic, it is expected to recover and grow from pre-pandemic levels in the coming years (ICAO, 2022). Projections from 2019 indicate that air travel emissions could account for a quarter of the global carbon budget by 2050 (Graver et al., 2019). Furthermore, when comparing different modes of transportation, air travel has the highest CO_2 emission per passenger kilometre (Rajendran & Popfinger, 2022). However, it has been observed that many consumers, despite being aware of the negative environmental impact, remain unwilling to change their travel behaviour (Cohen & Higham, 2011; Hares et al., 2010). Consequently, the lack of willingness to modify travel behaviour suggests an opportunity to provide individuals with the option to offset the emissions generated by their air travel activities.

2.2 Carbon offsetting

Achieving carbon neutrality requires the removal of emitted carbon from the atmosphere through carbon capture technologies or land-use changes that enhance carbon absorption (Jones, 2023; Wu et al., 2022). There are two types of offsetting programs affecting airlines and travellers: regulatory programs mandated by governing bodies and voluntary programs that organisations can participate in outside of regulatory frameworks (Greenhouse Gas Management Institute [GHGMI] & Stockholm Environment Institute [SEI], n.d.).

Regulatory policies include initiatives such as the EU Emission Trading System (ETS), UK ETS, and the International Civil Aviation Organization (ICAO) carbon offsetting and reduction scheme for international aviation (CORSIA). The EU ETS and UK ETS programs regulate aviation emissions within the European Economic Area and the United Kingdom, respectively. They provide airlines with tradeable allowances for a specified level of emissions from their flights each year (Department for Business, Energy and Industrial Strategy, 2023; European Commission, n.d.). While these and other country-specific programs oversee emissions from local air travel, CORSIA aims to regulate emissions from international air travel (ICAO, 2022). Under these regulations, aircraft operators are responsible for offsetting their CO_2 emissions from international flights through eligible programs, which employ diverse methods such as forestry, agriculture, and renewable energy. CORSIA was established in 2016 and is currently in its pilot phase, during which countries have volunteered to participate. Phase one will commence from 2024 to 2026, followed by phase two spanning from 2027 to 2035. As of July 2022, 115 countries have volunteered to participate.

Furthermore, airlines and passengers have the option to purchase a voluntary carbon offset (VCO) as an additional measure beyond regulatory compliance (Rotaris et al., 2020). Similar to CORSIA carbon offsets, VCOs are invested in carbon capture projects such as reforestation and renewable energy and can be verified by third-party organisations. In a report that analysed airlines' voluntary offset programs, Zelljadt (2016) found that 12 major airlines offer customers the opportunity to offset their flight emissions by supporting carbon reduction initiatives. Each airline sets its own price per tCO_2, which may vary depending on the availability of multiple offset programs for customers to choose from. Prices ranged from \$3 to \$128 per tCO_2, with a median price of \$15 per tCO_2. However, most of the airlines do not have enough information publicly available for determining participation rates or the extent to which these programs offset emissions. Among the airlines with available data, offsetting efforts appear to mitigate less than 1% of their emissions.

2.3 Previous research and research gap

The topic of offsetting aviation emissions has attracted significant research attention due to its importance in mitigating climate change and the increasing levels of air travel. The existing body of research in this area covers a wide range of contexts and circumstances. Some researchers, such as Brouwer et al. (2008), Hinnen et al. (2017), and Lu and Shon (2012) have focused on investigating consumers' WTP for VCOs. Others, such as Sonnenschein and Smedby (2019), have examined WTP for carbon surcharges. Various studies have also explored the influence of specific attributes on WTP. For instance, Ma et al. (2021) and Sonnenschein and Mundaca (2019) examined whether the choice of payment vehicle affected air travellers' WTP for offsetting. On the other hand, MacKerron et al. (2009), Ritchie et al. (2021), and Rotaris et al. (2020) investigated whether the type of offsetting project impacted consumers' offsetting preferences. Additionally, studies like Ma et al. (2021) and Seetaram et al. (2018) explored whether the distance travelled made a difference in WTP per tCO_2. Furthermore, the attributes of the studies themselves exhibit heterogeneity, including the currency used, the year of the study, the test methodology employed, and whether the WTP is measured per tonne or per flight.

Despite the abundance of available information, the existing studies on offsetting aviation emissions lack comparability, hindering the establishment of a unified measure of individuals' WTP. To my knowledge, no one has done a comprehensive analysis to synthesise and compare the existing findings. However, the significance of offsetting aviation emissions is evident from the large number of individual studies conducted on the topic. Meta-analyses have been successfully employed in other important areas of environmental economics, as demonstrated by Subroy et al. (2019) in their study on WTP to support wildlife, as well as by Ma et al. (2015) and Sundt and Rehdanz (2015) in their research on renewable energy. Thus, the purpose of this thesis is to bridge the gap by transforming the results of existing studies into a standardised measurement and investigating the factors and contextual influences that may account for the differences in their findings.

3. Theoretical positioning

In this section, the relevant economic theory will be discussed to develop hypotheses regarding the factors influencing individuals' WTP for reducing air travel emissions and the reported values. First, it will consider how individuals might be motivated to reduce or offset their emissions, then it will review the conceptual basis for obtaining monetary welfare estimates like WTP.

3.1 Motivations for climate change mitigation

This section will analyse economic theory to consider the motivations behind individuals' willingness to reduce or offset their emissions from air travel and the factors that may influence the value they place on these actions. According to Liebe et al. (2011), several competing theories can contribute to the determination of individuals' WTP for environmental goods. In the context of emissions from air travel, the following are considered to be the most relevant determinants of WTP and will be discussed in the following sub-sections: (1) public goods and the theory of warm glow; (2) the free-rider problem; (3) perceived credibility and uncertainty; and (4) environmental consciousness.

3.1.1 Public goods and the theory of warm glow

The emissions produced from air travel contribute to the total level of GHG in the atmosphere and deteriorate the overall environmental quality (Lee et al., 2009). According to Liebe et al. (2011), environmental quality is a public good because it is non-rivalrous and non-exclusive. Moreover, since environmental quality is affected by the aggregate of global consumer and producer emissions, it is determined by agents other than the individual, defining it as an externality (Phaneuf & Requate, 2016).

A basic model of externalities is presented as $U_i = U_i(x_i, G)$, where x_i represents a vector of goods and G is the exogenous level of the public good, both of which have positive first-order conditions (Andreoni, 1988). From this model, we can interpret that lower emissions would increase an individual's utility through improved environmental quality, G. However, there is a cost to reducing emissions, which decreases the consumption possibilities from x_i. Therefore, an individual must decide which option will provide them with more utility. In the context of air travel, the emissions from a single trip have a negligible impact on the global level of GHG, which begs the question – why would someone reduce their consumption of other goods, x_i, when there would be no noticeable improvement to G? Andreoni (1990) provides an explanation referred to as the *theory of warm glow*, which states that the act of giving itself provides utility.

The foundation of this theory is to explain why an individual contributes to a public good. The model developed by Andreoni (1990) is as follows:

$$U_i = U_i(x_i, G, g_i), i = 1, \ldots, n$$

Where n is the total number of individuals, $G = \sum^{n}_{i\text{-}1} g_i$, and U_i is assumed to be quasi-concave. From this it can be seen that an individual's contribution enters the utility function twice – once as part of a public good, G, and again as a private good, g_i. Therefore, if the warm glow, g_i, is significant enough, an individual will contribute to the public good even if their contribution has an inconsequential impact on the aggregate public good (Cherepanov, 2013). In the case of emissions from air travel, the aggregate level of GHG emissions inversely affects environmental quality, G, and an individual's mitigation of those emissions can be defined as m_i. Therefore, the model can be expressed as:

$$U_i = U_i(x_i, G, m_i), i = 1, \ldots, n$$

Where $G = \sum^{n}_{i\text{-}1} m_i$ and the following first-order condition is defined:

$$\frac{\partial U_i}{\partial m_i} > 0$$

These definitions imply that an individual's mitigation of their emissions is a normal good, and thus will increase with income. Therefore, the following hypothesis is derived:

***H1**: WTP is positive and increasing in income.*

3.1.2 The free-rider problem

In economic theory, the presence of public goods often highlights the free-rider problem. This problem arises because individuals are incentivised to refrain from contributing to the provision of a public good since they can enjoy the benefits of the public good regardless of whether they personally contribute (Kim & Brook, 1984; Liebe et al., 2011). Although there would be a greater benefit if everyone contributed, many individuals recognise the opportunity to benefit from the contributions of others. Therefore, when contributions are voluntary, impurely altruistic individuals will be motivated to rely on the benefit from other people's contributions (Menges et al., 2005). To minimise the free-riding incentive, many studies prefer to use tax schemes rather than donations as the proposed payment vehicle (Bishop, 2018). As a result, individuals become more likely to be willing to pay because they trust that other people are contributing too (Liebe et al., 2011). Additionally, using taxes as the payment vehicle rather than voluntary methods increases the likelihood that the aggregate contributions will make a meaningful impact on the total emissions mitigation. Therefore, through a compulsory offsetting scheme, the individual's benefit is not solely from the "warm glow", but also from the assurance that there can be an improvement to the overall level of emissions.

On the other hand, some theories suggest that WTP in a voluntary setting would be higher than in a compulsory program. The theory of warm glow asserts that people prefer to give voluntarily rather than involuntarily because it elevates the warm glow effect, which is not provided through taxation (Andreoni, 1990; Bishop, 2018; Chilton & Hutchinson, 2000). Additionally, some people have an aversion to tax increases and would therefore have a greater WTP with voluntary payment vehicles (Carson & Groves, 2007; Phaneuf & Requate, 2016).

Since there are two possibilities for how an individual's WTP may be affected by the payment vehicle, the following hypothesis is formed:

***H2**: WTP is affected by the payment vehicle and may increase or decrease when the contribution is voluntary.*

3.1.3 Perceived credibility and uncertainty

An important factor that influences how an individual values a product is their perception of its ability to perform as it claims (Demirgüneş, 2015; Kemp & Bui, 2011; Sweeny et al., 1999). In general, credibility reduces the risk for the consumer, thereby increasing their purchase intention and consumption value (Kemp & Bui, 2011). This concept holds true in the case of environmental goods. Many studies have shown that consumers' engagement in pro-environmental behaviour depends on trust and credibility (Amin & Tarun, 2021; Carrete et al., 2012; Sharma, 2021). A study about green consumer behaviour by Straughan and Roberts (1999) concludes that perceived effectiveness is the most important element to adopt pro-environmental consumer behaviour. Furthermore, this finding is supported by Han and Yoon (2015) and Manosuthi et al. (2020), who found that consumers' decision to engage in pro-environmental behaviour was most affected by their belief in the effectiveness of their actions to produce the desired outcome. Therefore, it means that air travellers need to believe that their contribution will be effectively used to truly offset the emissions.

The most straightforward way to raise the credibility of an environmental good is to show certifications that the product is verified by a third party. In a study by Carrete et al. (2012), it was found that many people have low levels of trust regarding environmental products from firms and government institutions, and therefore need transparent third-party certifications. Furthermore, Taufique et al. (2017) found that providing externally validated information improves pro-environmental consumer behaviour. For air travel emissions, this is done via certified offset credits. If the passenger sees that the VCO is certified, they have more assurance that their payment will be effectively used to offset the carbon emissions.

Another way to demonstrate credibility is to increase the specificity of the carbon offsetting claim. Many studies have found that specific claims regarding environmental products are considered more credible than vague claims (Borchers et al., 2007; Ganz & Grimes, 2018; Taufique et al., 2017). Therefore, it is expected that a consumer would place a higher value on an offsetting program that is transparent about the details than one which is vague.

Overall, the perceived credibility of the offsetting program will influence the way the air traveller values it. Therefore, the following hypothesis is established:

H3*: WTP increases with the level of credibility of the offset program, which may be demonstrated by third-party certification or by clear specifications of how the funds will be used.*

3.1.4 Environmental consciousness

Many studies have shown that an individual's decision to engage in pro-environmental behaviour is directly related to that person's awareness and attitudes about the environment and climate change (Boo & Park, 2013; Chan et al., 2014; Han & Hyun, 2017; Kaiser et al., 1999). In a systematic review of research about public support for climate policies, Drews and van den Bergh (2016) found that knowledge, beliefs, and opinions about climate change were among the main factors influencing support for environmental policy. Similarly, Liebe et al. (2011) found that WTP for public environmental goods increased with a more favourable attitude toward those goods. These results are explained by the theory of reasoned action, which asserts that an individual's behavioural intention and corresponding action are defined by their attitude toward the behaviour (Fishbein & Ajzen, 2011; Han, 2021). In addition to being concerned about environmental issues, Babutsidze and Chai (2018) found that people who also possessed more knowledge of climate change were more likely to act on their concerns. Therefore, it is likely that the more knowledgeable a person is about climate issues, the more likely they are to support emissions offsetting.

Furthermore, there are indications that environmental knowledge and concern strongly correlate with age and education, where younger individuals, as well as highly educated individuals, are more likely to be environmentally conscious than older, or less educated individuals (Carrete et al., 2012; Straughan & Roberts, 1999). Additionally, the public's awareness of environmental issues has been rising over time (Hares et al., 2010; Higham et al., 2016; Rotaris et al., 2020; Taufique et al., 2017). With air travel in particular, Cohen and Higham (2011) found that travellers are becoming more aware and concerned about emissions from aviation than they were in the past. Similarly, Gössling et al. (2008) predicted that climate concerns would begin to play a larger role in travel decisions in the future due to emerging environmental awareness.

These observations lead to the following hypothesis:

***H4**: WTP increases with the level of environmental consciousness, indicated through younger age, higher education, and more recent time.*

3.2 Environmental valuation

There are multiple ways to estimate a consumer's WTP to reduce emissions, and the choice of approach has the potential to influence the valuation elicited. Revealed preference techniques can be used to directly measure the value if there is an observable market for emissions reduction or carbon offsetting (Hands, 2013). The revealed preference approach relies on standard demand theory to estimate consumer surplus welfare measures through observing consumption decisions with the assumption that individuals make choices to maximise utility. However, this is not always possible since carbon offsetting is relatively new and does not exist in all regions or circumstances (Sonnenschein & Mundaca, 2019). Furthermore, revealed preference theory does not allow researchers to control for market contexts and influencing factors, which may be disadvantageous in exploratory studies (MacKerron et al., 2009).

As an alternative, researchers can find non-market values using stated preference techniques that are based on indirect utility theory to measure consumer welfare when there is no observable market for a good (Phaneuf & Requate, 2016). The two most common stated preference approaches are contingent valuation (CV) and choice experiments (CE). CV asks respondents to indicate their maximum WTP to obtain or retain a public good based on a series of bids that they may accept or refuse (Bateman et al., 2002; Kahneman & Knetsch, 1992; Phaneuf & Requate, 2016). Alternatively, CE asks respondents to indicate their preferred choice from a set of alternatives designed to resemble real market choices (Breidert, 2007; Hanley et al., 2001; McFadden, 1986). The choice sets can include many different attributes of interest, which are presented to respondents in varying combinations and prices, thus allowing the researchers to analyse the relative importance of each attribute. The ability to study individual attributes in CE can be highly informative, however, the complexity of choice alternatives compared to the bid format of CV surveys increases the cognitive burden for the respondent and could alter the results (Hanley et al., 2001). On the other hand, it has been found that CV results can be influenced by the amount of the starting bid used in the test (Brouwer et al., 2008; Lu and Shon, 2012; Zahedi et al., 2019). Additionally, all stated preference methods are inherently at risk for hypothetical bias (Harrison & Rutström, 2008; Murphy et al., 2005; Phaneuf & Requate, 2016).

Due to the risk of hypothetical bias, there may be a difference between stated and revealed WTP, especially for "warm glow" goods (Chilton & Hutchinson, 2000; Kahneman & Knetsch, 1992; Nunes & Schokkaert, 2003). The warm glow value is based on an individual's aspirations, and the hypothetical nature of stated preference models emphasises the respondent's aspirations rather than the realistic cost, thereby inflating the elicited value (Cherepanov et al., 2013). Moreover, according to Bishop (2018), "people answering CV questions take advantage of the opportunity to gain positive feelings from supporting the environment and other worthwhile causes, all at no cost since the payments referred to in CV questions are hypothetical" (p. 308). In addition, many researchers have identified an attitude-behaviour gap regarding environmental goods, where an individual's actions do not align with the pro-environmental attitudes they express (Babutsidze & Chai, 2018; Farjam et al., 2019; Higham et al., 2016; Taufique et al., 2017). Therefore, the following hypothesis is formed:

H5*: Stated preference estimates will yield higher WTP values than revealed preference methods.*[1]

4. Methodological approach

This section describes the methodological approach employed to conduct the meta-analysis. Procedures for primary study search protocol and selection criteria, effect size determination and standardisation, moderator variable selection, and data coding are described. The methodology used has been guided by the framework and best practices defined by Havránek et al. (2020) and Nelson and Kennedy (2009).

[1] Unfortunately, H5 was not able to be tested in the empirical analysis, as there was only one revealed preference study available for inclusion. However, it is assessed qualitatively in Section 6.

4.1 Search protocol and selection criteria

The literature search was conducted by searching the academic databases Oria, Science Direct, Scopus, EBSCO, ProQuest, Web of Science, Research Gate, and Google Scholar. The search terms used were combinations of “willingness-to-pay,” “contingent valuation,” “discrete choice experiment,” “carbon offsets,” “carbon offsetting,” “emissions reductions,” “sustainable,” “air travel,” “plane,” and “aviation.” Records could be from peer-reviewed journal articles, as well as from other materials, such as conference papers or dissertations.

Each study that was identified was assessed against the following criteria to determine whether it should be included in the meta-analysis:

1. Must pertain to consumers’ WTP for emissions reduction or carbon offsetting from air travel.
2. Must be an original study, not a duplication or re-publication of past research.
3. Must have full text available.
4. Must have a measurable WTP value that can be reasonably converted to a common effect size (described further in Section 4.2).

Each primary study that meets all criteria is included in the meta-analysis. The search was conducted from January to April 2023 and yielded 80 studies, of which 31 met the criteria for inclusion. Following the recommendation of Havránek et al. (2020), Figure 1 summarises the stages of the literature search identification, screening, and eligibility for inclusion using a so-called PRISMA flowchart (refer to Appendix A for a complete list of records identified).

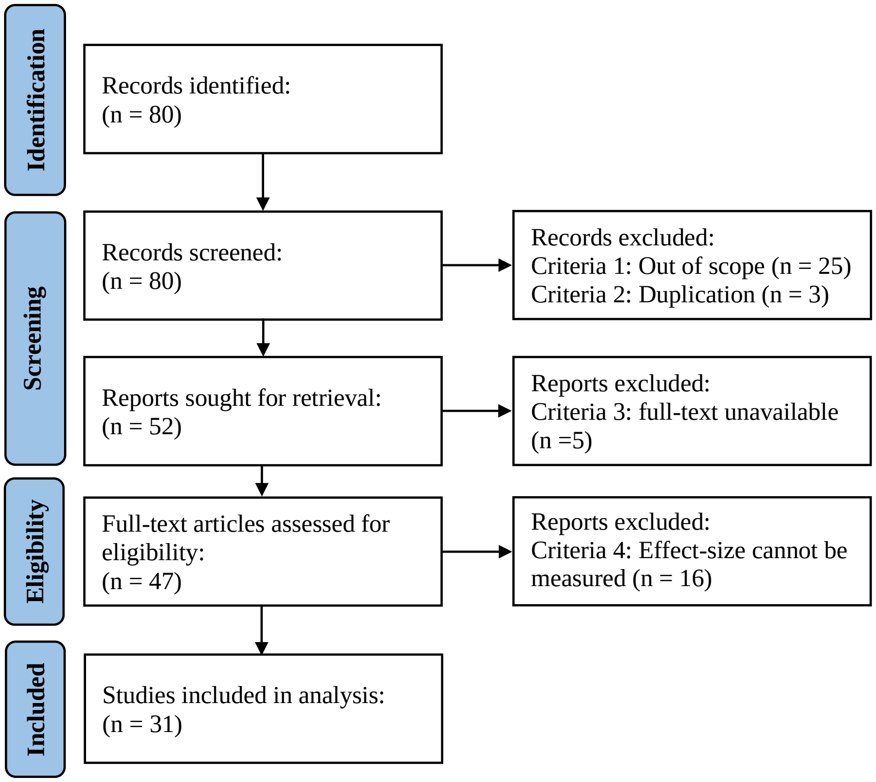

Figure 1. PRISMA flowchart. Adapted from Moher et al. (2009).

4.2 Effect size

In meta-analyses, the term "effect size" is used to describe the dependent variable, which is the standardised findings drawn from each primary study (Ma et al., 2015; Nelson & Kennedy, 2009). As such, it is crucial that it is uniformly measured across all studies. This analysis focuses on WTP to reduce emissions in air travel; therefore, the effect size should measure a payment amount in a common currency per unit of carbon emissions. The currency that will be used is USD since it is the most common metric for international comparisons and will be adjusted to 2021 values to account for inflation. Furthermore, WTP will be measured per tCO_2 as this provides a comparable basis for the level of emissions from a flight.

To bring all primary studies to the common metric, several conversions are necessary. Adopting methods used by Brouwer et al. (2022), Lindhjem (2007), and Subroy et al. (2019) the following key steps are performed:

1. Convert WTP estimations to equivalent units, i.e., tCO_2.

2. Use the World Bank's purchasing power parity (PPP) conversion factors to convert the study's local currency to international dollars (where USD is normalised to one international dollar).
3. Use USD inflation rates to obtain the 2021 value.

The conversion to tCO_2 in step (1) often requires finding the total emissions from a particular flight scenario that was used in the primary study. Studies commonly measure WTP using flight scenarios either in terms of location (e.g., a flight from London to New York) or of time (e.g., a four-hour flight). A reliable way to estimate the emissions per passenger per flight is the ICAO carbon emissions calculator, which is a tool supported by the UN to quantify the CO_2 footprint of air travel (ICAO, n.d.). Therefore, hypothetical flights that are representative of the scenario used in a primary study are entered into the ICAO calculator to obtain a measure of tCO_2. Furthermore, regarding currency conversion in step (2), some studies perform their own conversion from the local currency and present their results in USD. To be consistent with the methodology, these results are transformed back to the local currency using the US Federal Reserve nominal exchange rate at the time of the study and then converted to USD using the PPP conversion factor.

4.3 Moderator variables

Each primary study that is selected for inclusion is reviewed and coded into a dataset containing moderator variables that characterise the relevant information about the study's attributes, methods, and results. The moderator variables must be able to measure the true differences in effect sizes across settings, as well as account for differences in primary study design and model specification (Ma et al., 2015). To achieve this, the data coding procedure was an iterative process where the variables of interest were developed as more and more studies were examined. The complete set of variables is discussed below and summarised in Table 1.

First, variables that could explain true differences in an individual's WTP to offset emissions were considered. The focus was initially and primarily on the explanatory variables with a priori expectations established in Section 3.1, including respondent income (H1), whether the payment vehicle is voluntary or compulsory (H2), the perceived credibility of the offsetting scheme (H3), respondent age and level of education (H4), and the year of the study (H4).

Respondent income is the mean of the study's respondent's household income converted to 2021 USD using the PPP conversion factor. The payment vehicle is coded into a dummy variable to indicate whether the offsetting scheme used in the study was a hypothetical compulsory payment, such as a carbon tax, or a voluntary payment, such as a VCO. The perceived credibility of the offsetting scheme is coded as a dummy variable to indicate whether there was or was not an indication of credibility; to minimise ambiguity and the use of judgement, an offsetting scheme can be considered to have the perception of credibility if its use was clearly specified (for example, if the respondents were informed that the funds would be used in a particular environmental project or to purchase a certified offset credit). Age is the mean age of the sample respondents, education is the share of respondents with tertiary education, and the year is when the study was conducted.

Furthermore, while reviewing the literature, additional elements were revealed to have potential importance to explain differences in the effect size and were also added as moderator variables. These include flight distance, respondent gender, study location, whether the offset was framed to the respondent as "per flight" or "per tCO_2," whether the offsetting was in the form of a direct reduction of carbon emissions, and whether the offsetting scheme included co-benefits. The flight distance is classified as either long or not long, where long is defined as a flight time greater than six hours based on the International Air Transport Association flight haul specification. Gender is coded as the share of females included in the sample, and location is divided into regions (Europe, North America, Asia, and the rest of the world), which are coded as a series of dummy variables. Another series of dummy variables were also considered to denote the type of offset project since some studies found that people preferred one program type over another; however, not enough studies reported these details, so these variables were ultimately omitted as it was not possible to do a meaningful cross-study analysis.

Second, meta-analyses should include data about the study's method, empirical setting, and alternative ways that effects were measured before being converted to the common effect size (Havránek et al., 2020; Nelson & Kennedy, 2009). Therefore, variables are also coded for the study's sample size, the testing method used, the year the study was published, type of publication (journal article or other source), and how many data points are taken from the study. Havránek et al. (2020) also suggest including variables for the omission of theoretically relevant variables in the study. The theoretically relevant variables that are identified based on the literature review include the respondent's education, age, gender, income, and knowledge or attitudes about environmental issues and CO_2 emissions.

Table 1

Moderator variables

Variable	Description
Effect size:	
WTP_converted	WTP per tCO_2 in 2021 USD
Explanatory variables:	
Year_study	Year of study's data collection
Region_Europe	Dummy: 1 = Europe; 0 = other
Region_NAmerica	Dummy: 1 = North America; 0 = other
Region_Asia	Dummy: 1 = Asia; 0 = other
Region_Other	Dummy: 1 = rest of world; 0 = other
Distance_long	Dummy: 1 = long flight (> 6 hours); 0 = other
Income_converted	Mean income of study's respondents in 2021 USD
Age	Mean age of study's respondents
Female	Share of sample that are female
Higher_edu	Share of sample with tertiary education
Credible	Dummy: 1 = credible (certified or use specified); 0 = other
Voluntary	Dummy: 1 = voluntary; 0 = compulsory
Unit_tCO2	Dummy: 1 = presented as tCO_2; 0 = other measurement unit (per flight)
Direct_reduction	Dummy: 1 = direct reduction of CO_2; 0 = other
Cobenefit	Dummy: 1 = offset includes co-benefit; 0 = other
Study variables:	
Sample_sizeN	Study's sample size
Model_CV	Dummy: 1 = contingent valuation; 0 = other
Model_CE	Dummy: 1 = choice experiment; 0 = other
Model_RP	Dummy: 1 = revealed preference; 0 = other
Year_published	Year the study was published
Source_journal	Dummy: 1 = peer-reviewed journal; 0 = other
Incl_education	Dummy: 1 = education level was included in WTP estimation; 0 = not included
Incl_age	Dummy: 1 = age was included in WTP estimation; 0 = not included
Incl_gender	Dummy: 1 = gender was included in WTP estimation; 0 = not included
Incl_income	Dummy: 1 = income was included in WTP estimation; 0 = not included
Incl_knowledge	Dummy: 1 = knowledge about CO_2 emissions was included in WTP estimation; 0 = not included

4.4 Data coding procedure

An important consideration in meta-analyses is how many observations should be extracted from each primary study since many studies report more than one WTP estimate (Nelson & Kennedy, 2009). Multiple approaches can be utilised, each with its advantages and disadvantages. Some meta-analyses, such as those by Florax et al. (2005), Johnston et al. (2006), and Kochi et al. (2006), take numerous effect size estimates from each primary study, which may be available due to in-study variations or valuation methodology that the study employed. While this method increases the number of observations, it can lead to within-study autocorrelation and complicate the empirical model. On the other hand, some meta-analyses opt to reduce the number of observations taken from a primary study by averaging estimates that could not be distinguished by the explanatory variables, which can help simplify the statistical model (Brouwer et al., 2022; Lindhjem, 2007). Therefore, two versions of data coding will be used in the analysis. Sample 1 extracts as many observations as possible. For example, in a primary study that reports its findings using an array of models that yield slightly different WTP estimates, all estimates will be coded as their own observations in the meta-analysis. Sample 2 limits observations to those that can be uniquely identified through one of the moderating variables and using an average otherwise. That is, if a study has multiple observations that are not differentiated in a way that can be reflected in the meta-analysis variables, such as belonging to different cities that are within the same global region or consumer segments based on behavioural and attitudinal characteristics, these segments will be aggregated and averaged into one observation in the meta-analysis. Conversely, if the estimates provided in the primary study do vary based on one of the moderator variables, such as the payment vehicle or flight length, each will be its own observation in the meta-analysis.

In the coding process, several assumptions had to be made to fit each primary study within the same set of moderator variables. In meta-analyses there is a trade-off between leaving moderator variables blank, resulting in fewer valid observations for each, and having to make an approximation based on outside information (Lindhjem, 2007). When reasonable, assumptions were made to reduce the number of observations with insufficient data, which would lower the explanatory power of the empirical study. When income information is not available, the mean household income is determined using official income figures from the study's location, which is a widely used technique (Johnston et al., 2006; Ma et al., 2015; Subroy et al., 2019). If the sample’s gender information was unavailable, it was assumed to be equally comprised of males and females. Studies that had respondents from multiple regions but with aggregated WTP estimates are assigned to the region that had the highest proportion in the sample. However, not every element is possible to approximate, such as the share of the sample with tertiary education, and were therefore left blank if unknown. There were a couple of studies that had significant amounts of missing information for both the moderator variables and the effect size calculations, though they are still used in the primary analysis using approximations; however, acknowledging that they may be less precise than other studies, they were identified to be reconsidered in the sensitivity analysis in Section 5.4.

5. Results and analysis

This section presents the results of the meta-analysis. It includes an overview of the primary studies and data, an explanation of the meta-regression model development, and its results. Additionally, a sensitivity analysis is conducted to assess the robustness of the findings. Furthermore, a qualitative review of each primary study is provided to offer additional insights. The analysis is conducted using R Statistical Software version 4.2.3 (R Core Team, 2023).

5.1 Overview of primary studies

The literature search resulted in 31 useable primary studies for the meta-analysis, which are summarised in Table 2. These studies were first published in 2008 and continued through to 2022. Fourteen (45%) of these were from European countries, seven (23%) from Asian countries, six (19%) from Australia, two (6%) from the United States, and two (6%) that include multiple locations. Furthermore, sixteen (52%) of the studies were conducted using the CE method, while thirteen used the CV method (42%), and one study used both. Only one study used the revealed preference method.

Most of the primary studies yielded multiple WTP estimates, with an average of seven observations per study in Sample 1 (223 total) and two observations per study in Sample 2 (73 total). Numerous observations were recorded in Sample 1 due to several studies reporting their results using multiple statistical techniques, as well as dividing their sample into consumer segments, such as individuals who are “green consumers” or “cost-conscious.” However, some of these individual estimates were retained in Sample 2 if they varied based on elements that could be reflected in the moderator variables of the meta-analysis, such as separate WTP estimates for offsetting emissions from a short flight or in a long flight.

Table 2

Overview of primary studies

Study	Location	Number of Observations Sample 1	Number of Observations Sample 2	WTP ($/t$CO_2$)	Method
Akter et al. (2009)	Netherlands	11	1	$8 - $97	CV
Alfaro & Chankov (2022)	Online (Primarily N. America)	4	4	$80 - $314	CE
Araghi et al. (2016)	Netherlands	3	1	$2 - $42	CE
Berger et al. (2022)	Switzerland	1	1	$1	RP
Blasch & Ohndorf (2015)	Switzerland & United States	8	2	$0 - $50	CE
Brouwer et al. (2008)	Netherlands	3	3	$31 - $62	CV
Carroll et al. (2022)	Ireland	1	1	$105	CE
Cheramakara (2014)	Thailand	4	2	$35 - $206	CE
Cheung et al. (2015)	Australia	6	1	$7 - $129	CE
Choi & Ritchie (2014)	Australia	1	1	$16	CE
Choi (2015)	Australia	6	2	$8 - $43	CV
Choi et al. (2018)	Australia	8	2	-$2 - $22	CE
Denstadli & Viesten (2020)	Norway	27	2	$98 - $711	CV
Fatihah & Rahim (2017)	Malaysia	1	1	$6	CV
Hagmann et al. (2015)	Germany	1	1	$1	CE
Hinnen et al. (2017)	Switzerland	4	1	$23 - $414	CE
Jou & Chen (2015)	Taiwan	48	14	$24 - $78	CV
Lu & Shon (2012)	Taiwan	4	4	$51 - $71	CV
Ma et al. (2021)	China	4	4	$14 - $92	CV
MacKerron et al. (2009)	United Kingdom	6	3	$23 - $45	CV & CE
Rice et al. (2020)	United States	5	3	$64 - $496	CE
Ritchie et al. (2021)	Australia	13	1	-$26 - $380	CE
Rotaris et al. (2020)	Italy	15	4	$19 - $202	CE
Sanguinetti & Amenta (2022)	United States	2	2	$195 - $265	CE
Schwirplies et al. (2019)	Germany	18	1	$59 - $92	CE
Seetaram et al. (2018)	United Kingdom	6	2	$18 - $141	CV
Shaari et al. (2020)	Malaysia	1	1	$72	CV
Shaari et al. (2022a)	Malaysia	1	1	$38	CV
Sonnenschein & Mundaca (2019)	Sweden	3	3	$17 - $69	CV
Sonnenschein & Smedby (2019)	Sweden	4	2	$37 - $69	CV
Zhang et al. (2022)	Australia	4	2	$3 - $48	CE

Note. Abbreviations: CV = contingent valuation; CE = choice experiment; RP = revealed preference.

The WTP estimates from these studies vary greatly, from as low as negative \$26 per tCO_2 up to \$711 per tCO_2, with means of \$103 in Sample 1 and \$72 in Sample 2. The spread of WTP estimates from both samples is displayed in Figure 2. In the Sample 1 data set, the range of WTP estimates is wider, with fewer estimates clustered around the mean and more with higher values. However, in the Sample 2 data set, when averaging is applied to reduce the number of observations per study, more of the estimates are closer to the mean value and the number of extreme values is reduced. Descriptive statistics for both samples are outlined in Table 3.

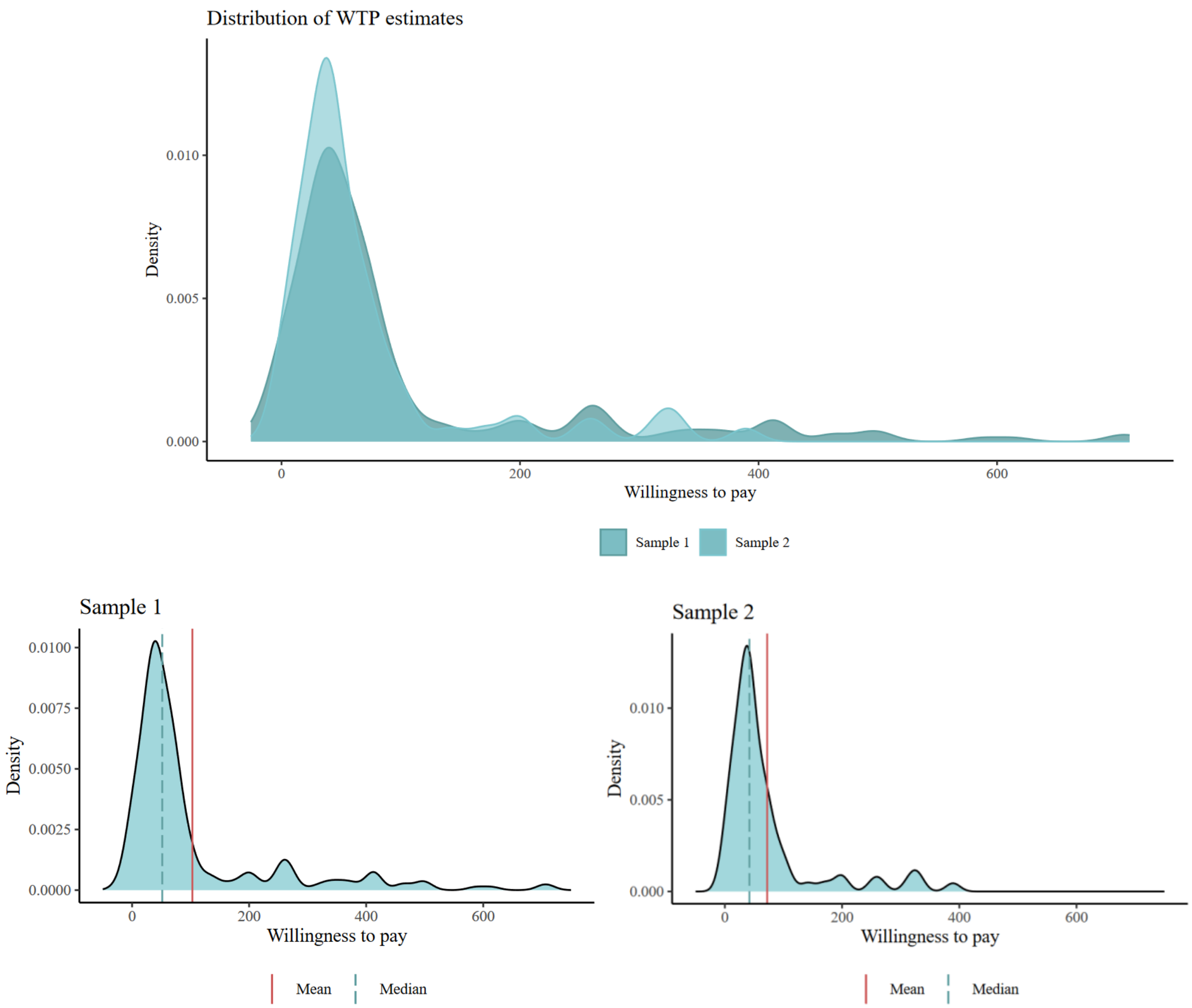

Figure 2. Distribution of WTP estimates

Table 3

Descriptive statistics

	Sample 1					Sample 2				
Statistic	N	Mean	St. Dev.	Min	Max	N	Mean	St. Dev.	Min	Max
Effect size:										
WTP_converted	223	103.036	135.241	-25.712	711.121	73	72.176	83.497	-0.739	389.211
Explanatory variables:										
Year_study	223	2014	4	2006	2022	73	2014	4	2006	2022
Region_Europe	223	0.471	0.500	0	1	73	0.342	0.478	0	1
Region_NAmerica	223	0.072	0.259	0	1	73	0.151	0.360	0	1
Region_Asia	223	0.287	0.453	0	1	73	0.384	0.490	0	1
Region_Other	223	0.170	0.377	0	1	73	0.123	0.331	0	1
Distance_long	221	0.222	0.416	0	1	71	0.352	0.481	0	1
Income_converted	223	62,257	24,148	13,533	112,191	73	58,196	22,458	13,533	109,959
Age	223	42.373	7.586	21.862	71	73	39.932	8.594	21.862	71
Female	223	0.537	0.135	0	1	73	0.549	0.157	0	1
Higher_edu	165	0.686	0.173	0	1	51	0.733	0.197	0	1
Credible	223	0.578	0.495	0	1	73	0.438	0.500	0	1
Voluntary	223	0.803	0.399	0	1	73	0.822	0.385	0	1
Unit_tonneCO2	223	0.197	0.399	0	1	73	0.260	0.442	0	1
Direct_reduction	223	0.058	0.235	0	1	73	0.151	0.360	0	1
Cobenefit	223	0.018	0.133	0	1	73	0.014	0.117	0	1
Study variables:										
Sample_sizeN	223	760.030	4242.006	15	63,520.00	73	1359.452	7387.536	20	63,520.00
Model_CV	223	0.543	0.499	0	1	73	0.562	0.500	0	1
Model_CE	223	0.453	0.499	0	1	73	0.425	0.498	0	1
Model_RP	223	0.004	0.067	0	1	73	0.014	0.117	0	1
Year_published	223	2017	4	2008	2022	73	2017	4	2008	2022
Source_journal	223	0.951	0.217	0	1	73	0.945	0.229	0	1
Incl_education	223	0.372	0.484	0	1	73	0.384	0.490	0	1
Incl_age	223	0.578	0.495	0	1	73	0.575	0.498	0	1
Incl_gender	223	0.587	0.493	0	1	73	0.534	0.502	0	1
Incl_income	223	0.498	0.501	0	1	73	0.479	0.503	0	1
Incl_knowledge	223	0.498	0.501	0	1	73	0.466	0.502	0	1

5.2 Meta-regression model

The meta-regression aims to identify factors that influence a person's WTP to offset emissions from air travel. Based on the model given by Lindhjem and Navrud (2015), and common practice in meta-analyses, an ordinary least squares (OLS) regression model can be used:

$$\ln(WTP_{si}) = \beta_0 + \beta_1 \ln(Income_{si}) + \sum_k \beta_k X_{si}(k) + \varepsilon_{si}$$

where $\ln(WTP_{si})$ and $\ln(Income_{si})$ are the natural logarithm of WTP and income, respectively, of estimate i from study s, β_0 is a constant term, β_1 is the coefficient for income, β_k is a vector of coefficients that correspond to the set of moderator variables X_k, and ε is the error term.

Additionally, in meta-regression analyses, there are concerns that each observation should not carry the same weight for two reasons. First, the estimates provided by some studies may be more precise than other studies, meaning that they had smaller variances. According to Nelson and Kennedy (2009), the estimates with lower variances are more reliable and should be given more weight in the meta-regression. However, for practical reasons, it is difficult or not possible to know the effect size variance of each observation. Therefore, an acceptable proxy to measure the level of precision is to use the primary study sample sizes instead. That is, the larger the study's sample size, the more reliable the estimate and the more weight it should take in the meta-regression. Second, weights should be adjusted to account for the imbalance that occurs from some studies providing more observations than others. Having primary studies with numerous estimates can lead to correlations between the effect sizes and heteroskedasticity, as well as cause the studies with more observations to be over-represented in the sample (Nelson & Kennedy, 2009; Subroy et al., 2019). One approach to correct this is to weigh each estimate from a primary study according to the number of observations taken from that study so that the weight of all observations from a primary study sum to one. Therefore, the regression model is adapted to a weighted least squares (WLS) model that assigns weights to each observation i, such that,

$$w_i = \frac{n_i}{N} * \frac{1}{E_s}$$

where n is the study's sample size for each i observation, with $N = \sum n_i$ and E_s is the number of observations taken from each s primary study.

Moreover, consideration is given to determine the moderator variables that would result in the most suitable and well-fitting model. Although all relevant variables identified in Table 1 were coded, there can be issues of multicollinearity, which would reduce the precision of the meta-regression results. Using a correlation matrix displayed in Figure 3, it is clear that a substantial correlation exists between some of the moderator variables. Additionally, certain variables were not available for every observation, leading to a reduction in the number of usable observations when including those variables. Therefore, improvements can be made to the regression model by excluding some of the variables. Several variations of regression models were performed to assess the impact of combinations of moderator variables on the overall fit for both Sample 1 and Sample 2 (refer to Appendix B for results). First, a preliminary regression was performed including all variables defined in Table 1, except for dummy variables that are used as references, namely *Region_Europe* and *Model_CV*. Second, omissions of correlated variables were assessed using a stepwise procedure. According to the correlation analysis, the moderator variables that specify the primary study's inclusion of relevant variables are all highly correlated with each other, though they do show significance in the preliminary results. Therefore, they are merged into one dummy variable, *Incl_vars*, for each subsequent version, where an observation is coded as "1" if at least three out of five of the original variables were positive. In addition, *Direct_reduction* is omitted because it is highly correlated with North American studies and was not selected with a priori expectations, nor did it have significance in the preliminary regression. Not surprisingly, the year the study was published is highly correlated with the year the study was conducted. Based on the theoretical position established in Section 3.1.4, the year the study was conducted has more relevance to this analysis and will therefore be retained, while the publication year will be omitted. With these adjustments applied to the second model, the R^2 decreased slightly but multicollinearity is addressed. Third, in an attempt to recapture the number of useable observations, the variable *Higher_edu* was excluded, as this information was missing in several primary studies. Although the number of observations increased substantially in both samples, the R^2 consequently decreased from 0.747 to 0.443 and from 0.830 to 0.351 in Sample 1 and Sample 2, respectively. Overall, the third model gains more observations but loses explanatory power with a substantial reduction in R^2 compared to the second model. Therefore, the second model will be used as the preferred model for further analysis.

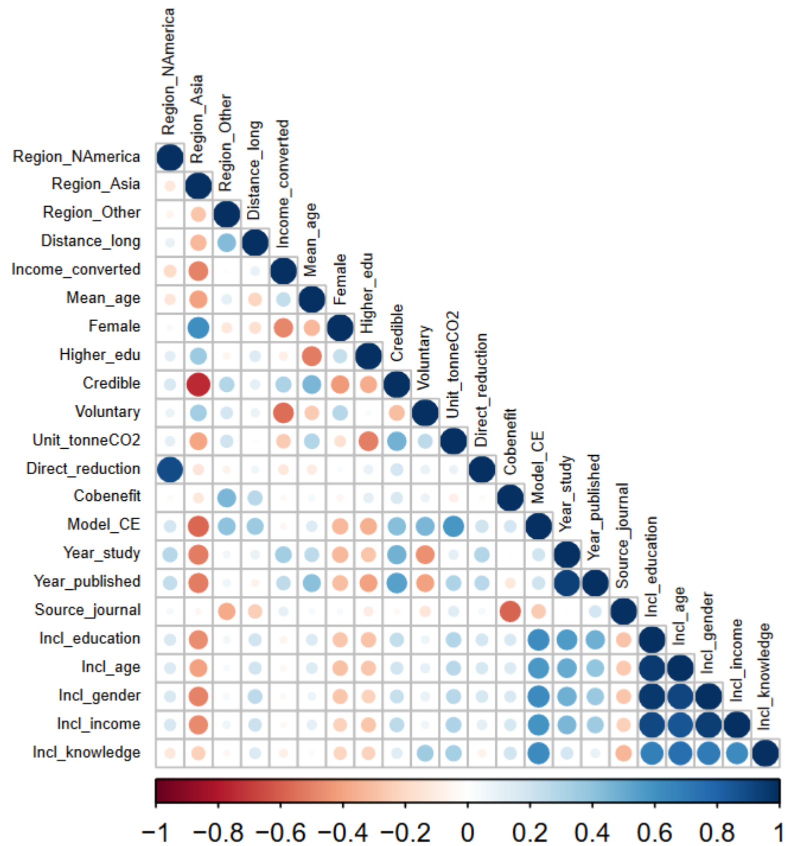

Figure 3. Correlation matrix[2]

5.3 Preferred model and results

Results for Sample 1 and Sample 2 using the preferred model are presented in Table 4. Overall, the model is a good fit, as can be seen by the adjusted R^2 of 0.719 and 0.746 for samples 1 and 2, respectively, as well as by F statistics that are significant at the one percent level. According to Nelson and Kennedy (2009), meta-analyses have an average adjusted R^2 of 0.480, indicating that this model performs very well in terms of overall fit. Results for the two samples are generally similar. There are some differences in the significance of explanatory variables, though the directional impact is consistent and of similar magnitude for those that do show significance. Sample 1 has more variables showing significance than Sample 2, specifically age, education, and

[2] The correlation matrix is based on the Sample 1 data set. Correlations in Sample 2 were also inspected and are not significantly different from Sample 1.

the presence of co-benefits. It makes intuitive sense that this would be the case since Sample 2 reduces the number of observations by averaging estimates from each study, which can lead to more homogeneity and reduce the impact of the causal factors.

Table 4

WLS regression results

	Dependent variable:	
	Log_WTP	
	Sample 1	Sample 2
Explanatory variables:		
Year_study	0.016 (0.025)	0.022 (0.045)
Region_NAmerica	0.991*** (0.362)	0.854* (0.484)
Region_Asia	0.095 (0.308)	0.149 (0.410)
Region_Other	-1.478*** (0.221)	-1.382*** (0.319)
Distance_long	-1.009*** (0.121)	-0.838*** (0.147)
Log_income	0.154 (0.273)	0.087 (0.369)
Age	0.030** (0.015)	0.017 (0.020)
Female	0.230 (1.541)	-0.706 (1.732)
Higher_edu	1.369** (0.559)	0.618 (0.948)
Credible	0.957*** (0.155)	0.810*** (0.235)
Voluntary	-0.315 (0.224)	-0.212 (0.304)
Unit_tCO2	-0.928*** (0.198)	-0.985*** (0.345)
Cobenefit	1.151** (0.489)	0.351 (0.605)
Study variables:		
Model_CE	0.036 (0.288)	0.296 (0.418)
Source_journal	0.120 (0.275)	-0.098 (0.403)
Incl_vars	0.125 (0.257)	0.023 (0.453)
Constant	-31.586 (49.565)	-41.474 (86.747)
Observations	162	49
R^2	0.747	0.830
Adjusted R^2	0.719	0.746
Residual Std. Error	0.015 (df = 145)	0.033 (df = 32)
F Statistic	26.726*** (df = 16; 145)	9.798*** (df = 16; 32)
Note:		*p<0.1; **p<0.05; ***p<0.01

The a priori expectations were that WTP would: increase with income (H1), the degree of credibility (H2), education (H4), and time (H4); decrease with age (H4); and be impacted positively or negatively by a voluntary payment vehicle (H3). The results in Table 4 confirm that credibility does have a positive impact on WTP and is significant at the one percent level in both samples, thus supporting H2. Since *Credible* is a dummy variable and the dependent variable (WTP) is in natural logarithm form, a transformation must be made to interpret its value[3] (Halvorsen & Palmquist, 1980). Accordingly, the coefficient value of 0.957 implies WTP increases by 160% if the offset is credible. The income and voluntary variables are not statistically significant, meaning that H1 and H3 are not supported in the meta-regression. Lastly, H4 is partially supported, since education is positive and significant in Sample 1, however, the year is not significant and age has the opposite effect as predicted, though it is only significant in one of the samples.

Interestingly, several other explanatory variables that were not identified in advance are highly significant. A respondent being from North America has a significant positive impact on WTP, while those from other regions have a significant negative influence on WTP. These variables are in reference to the baseline, which was set as respondents from European countries; therefore, it can be said that North Americans have higher WTP than Europeans, while people from other regions have lower WTP than Europeans, and there is no statistical difference between Asians' and Europeans' WTP. Worth noting here is that nearly all of the estimates from other regions happen to be from Australia, and thus, the interpretation can be applied to that country specifically. Additionally, WTP per tCO_2 is significantly lower when the travel distance is longer by a magnitude of 64% to 57% in samples 1 and 2, respectively. Presence of a co-benefit increases WTP, which can be expected, since the amount paid is not only for carbon offsetting but also for a secondary good. Finally, whether the offset is framed as "per tCO_2" instead of "per flight" is a factor that corresponds to approximately 60% lower WTP with significance at the one percent level in both samples.

[3] The effect of the coefficient of a dummy variable on a natural logarithm dependent variable is calculated as $g = \exp(c) - 1$, where g is the relative effect on the dependent variable and c is the dummy variable coefficient (Halvorsen & Palmquist, 1980).

5.4 Sensitivity analysis

In addition to the initial model development in Section 5.2, a sensitivity analysis should be performed to see how the results may differ if alternate assumptions are used (Nelson & Kennedy, 2009). Part of this sensitivity test was performed in the primary analysis through the use of two samples that were created using different methodologies; however, two additional scenarios will be considered for further analysis: (1) exclusion of primary studies that required substantial assumptions to convert the effect size; and (2) exclusion of outlier observations.

The first case is triggered by the need to have converted the results of each primary study into a common effect size, specifically having the WTP measured per tCO_2. In a few primary studies, there was not a lot of information given about the context with which WTP estimates were derived so more assumptions were needed to do the conversion. For instance, some studies reported a WTP value "per flight" but did not say the distance, duration, or locations of the flights. In such cases, average flight emissions were used, which roughly corresponds to a medium-haul flight. However, by using broad assumptions there is a greater chance that the WTP estimates are inaccurate and could skew the overall meta-analysis results. There were two studies, each with one observation in samples 1 and 2, that are excluded for this reason. Results for the adjusted meta-regression are presented in Model 1 of Table 5.

The second case accounts for outlier observations that are included in the primary analysis but may be disproportionately influencing the results. All observations were initially retained because they are valid data points and their inclusion was decided based on the predetermined criteria. However, their values may be the result of circumstances that are not reflective of the majority of the other observations, and as such, Nelson and Kennedy (2009) recommend using a sensitivity analysis to see if their exclusion causes a significant difference in the results. A Cook's Distance test was used to identify the outlier observations that distort the regression (Walfish, 2006), from which 12 and 7 observations were identified in Sample 1 and Sample 2, respectively. These observations were then removed from the samples, and the adjusted results can be seen in Model 2 of Table 5.

Table 5

Sensitivity analysis

	Dependent variable:			
	Log_WTP			
	Sample 1		Sample 2	
	(1)	(2)	(1)	(2)
Explanatory variables:				
Year_study	0.061** (0.028)	0.060*** (0.018)	0.076* (0.041)	0.016 (0.032)
Region_NAmerica	0.734** (0.361)	0.727*** (0.226)	0.495 (0.422)	0.958*** (0.278)
Region_Asia	-0.258 (0.318)	-0.555** (0.213)	-0.584 (0.387)	-0.418 (0.259)
Region_Other	-1.622*** (0.219)	-2.519*** (0.203)	-1.423*** (0.271)	-1.254*** (0.262)
Distance_long	-1.029*** (0.118)	-1.121*** (0.086)	-0.872*** (0.123)	-0.826*** (0.110)
Log_income	0.111 (0.267)	0.335* (0.171)	0.052 (0.315)	0.103 (0.238)
Age	0.036** (0.016)	0.032*** (0.011)	0.033* (0.018)	0.030** (0.013)
Female	0.101 (1.519)	0.681 (0.978)	-0.873 (1.459)	-0.610 (0.874)
Higher_edu	1.906*** (0.571)	2.221*** (0.421)	2.271** (0.893)	1.774** (0.730)
Credible	0.875*** (0.153)	0.660*** (0.113)	0.728*** (0.198)	0.458*** (0.141)
Voluntary	0.067 (0.259)	0.040 (0.153)	0.262 (0.304)	-0.013 (0.167)
Unit_tCO2	-0.776*** (0.198)	-0.328** (0.133)	-0.538* (0.309)	-0.290 (0.196)
Cobenefit	0.492 (0.515)	1.000** (0.464)	-1.415** (0.668)	-0.248 (0.593)
Study variables:				
Model_CE	-0.342 (0.305)	-0.271 (0.201)	-0.452 (0.398)	-0.389 (0.242)
Source_journal	-0.748** (0.378)	-1.338*** (0.317)	-2.002*** (0.579)	-0.885 (0.555)
Incl_vars	-0.015 (0.253)	-0.354** (0.169)	-0.104 (0.381)	0.070 (0.344)
Constant	-120.928** (55.106)	-121.356*** (35.437)	-148.861* (79.488)	-30.894 (62.880)
Observations	160	150	47	42
R^2	0.763	0.859	0.888	0.934
Adjusted R^2	0.736	0.842	0.828	0.892
Residual Std. Error	0.014 (df = 143)	0.009 (df = 133)	0.028 (df = 30)	0.018 (df = 25)
F Statistic	28.748*** (df = 16; 143)	50.565*** (df = 16; 133)	14.842*** (df = 16; 30)	22.139*** (df = 16; 25)
Note:				*p<0.1; **p<0.05; ***p<0.01

Compared to the preferred model in Table 4, the results of the sensitivity analysis in Table 5 indicate similar relationships with the coefficients and some improvements to the overall fit. The R^2 and adjusted R^2 are improved in all cases and the F statistics remain significant at the one percent level. Notably, the coefficient directions remain the same for every variable that was significant in the preferred model, indicating consistent relationships overall. However, some variables gain or lose significance in the alternate versions. North America is consistently positive (with reference to Europe), but it becomes less significant in the alternate Model 1 while becoming more significant in Model 2. Likewise, Asia was not significant (with reference to Europe) in the preferred model, but it does become significant and negative in Sample 1, Model 2. The income variable is consistently positive, and although it was initially not significant, it does become significant at the ten percent level in one of the alternate versions. Recall that income and WTP are both in the natural logarithm form, therefore, the coefficient of 0.335 represents the elasticity. Moreover, age and education gain significance compared to the original model. The year of the study also becomes significant with a positive coefficient in three out of four variations, implying that WTP increases by six or seven percent each year. Lastly, none of the study variables showed significance in the preferred models; however, in the alternate versions, the variable that indicates whether the study was in a published journal becomes significant and negative with a magnitude of 53% to 86% depending on the model variation.

5.5 Qualitative analysis

This section will discuss the factors that influence WTP that were identified at the primary study level but not through the meta-regression analysis. Assessing the results in this way enables insights that are not apparent at the meta-level due to averaging effects and the inherent inability to transfer all the information into comparable variables. The factors identified in each study are grouped by common themes that emerged during the analysis and are summarised in Table 6.

Environmental knowledge and attitudes

Individuals' beliefs and attitudes about environmental issues can predict their WTP to offset their air travel emissions. As seen in Table 6, most studies included some aspect to measure a respondent's knowledge of environmental issues, their engagement in pro-environmental behaviour, or their sense of responsibility for mitigating climate change. As expected, results consistently found that the greater degree of pro-environmental attitudes, the higher the WTP. Moreover, some studies noted that offsetting decisions are best explained by consumer segments defined by an individual's environmental attitudes and beliefs. Ritchie et al. (2021) identified market segments with different preferences, which differed in key personal characteristics, including age, employment status, frequent flyer membership, and flight behaviour, and the segment with the higher WTP was younger and more altruistic. Hinnen et al. (2017) also segmented their respondents and found that 20% fell into a “green” segment exhibiting strong preferences and higher WTP for offsetting.

Socioeconomic and demographic

When comparing socioeconomic and demographic characteristics, mixed results were found across studies. From the studies that controlled for gender, eight identified that females had higher WTP than males (Araghi et al., 2016; Choi & Ritchie, 2014; Ma et al., 2021; MacKerron et al., 2009; Rice et al., 2020; Rotaris et al., 2020; Sonnenschein & Smedby, 2019; Zhang et al., 2022), while two found no correlation between WTP and gender (Denstadli & Viesten, 2020; Shaari et al., 2020). Most of the studies that considered age found that younger people had higher WTP, but a few found that WTP increased with age (Denstadli & Viesten, 2020; Fatihah & Rehim, 2017; Shaari et al., 2020), and one study saw no correlation (Jou & Chen, 2015). Last and as expected, higher levels of education and higher income were consistently seen to increase WTP.

Offset project characteristics

Many studies found that there are preferences for certain types of offsetting projects over others. Most of the studies that investigated preferences for different project types found that respondents preferred those that were to be conducted locally as opposed to internationally (Cheung et al., 2015; Choi et al., 2018; Hinnen et al., 2017; Ritchie et al., 2021; Schwirplies et al., 2019; Zhang et al., 2022). However, the study by Choi and Ritchie (2014) found the opposite to be true, where the respondents preferred the projects that would take place in developing countries. Furthermore, two studies found that preference was given to renewable energy projects over reforestation projects (Cheung et al., 2015; Choi & Ritchie, 2014), but Schwirplies et al. (2019) had the opposite findings, as well as Rotaris et al. (2020) finding that afforestation was preferable to improving aircraft and fuel technology.

Table 6

Influencing factors identified within primary studies

	Influencing factors identified within study:		
Study	Environmental knowledge and attitudes	Socioeconomic and demographic	Offset project characteristics
Akter et al. (2009)	Sense of personal responsibility for climate change mitigation increases likelihood to offset		
Alfaro & Chankov (2022)			
Araghi et al. (2016)	More knowledge of air travel and climate change increases likelihood to offset	Females and middle-age are more likely to offset	
Berger et al. (2022)	Pro-environmental behaviour increases likelihood to offset	Higher income increases likelihood to offset	
Blasch & Ohndorf (2015)	Expectation of social recognition increases likelihood to offset	WTP increases with income	
Brouwer et al. (2008)	Sense of personal responsibility for climate change mitigation increases WTP	WTP is lower for Asians than Europeans	
Carroll et al. (2022)	More knowledge of and concern for climate change increases WTP		
Cheramakara (2014)	More awareness of carbon offsetting increases WTP	WTP increases with income	
Cheung et al. (2015)		WTP decreases with income and age; increases with education	Preference for local renewable energy projects over international reforestation projects
Choi & Ritchie (2014)	Perceived contribution of flights to climate change increases WTP	WTP higher for females	Preference for renewable energy projects projects in developing countries; technological efficiencies more strongly supported than operational practices and biofuels
Choi (2015)	Pro-environmental attitudes increase WTP	WTP increases with income	
Choi et al. (2018)			Preference for offset credits from domestic projects over international projects
Denstadli & Viesten (2020)		WTP increases with income and age; No correlation with gender or education	
Fatihah & Rahim (2017)		WTP increases with income and age	
Hagmann et al. (2015)			

Table 6, continued

Study	Influencing factors identified within study: Environmental knowledge and attitudes	Socioeconomic and demographic	Offset project characteristics
Hinnen et al. (2017)	Pro-environmental behaviours and attitudes increase WTP		WTP more for local carbon offset projects than in developing countries
Jou & Chen (2015)		WTP increases with income and education; No correlation with age	
Lu & Shon (2012)	Higher knowledge of offset schemes increases WTP	WTP decreases with age	Higher WTP if responsibility for offsetting is shared between the airline and passengers
Ma et al. (2021)	Higher environmental concern increases WTP	WTP increases with income; Females have higher WTP	
MacKerron et al. (2009)		Females have higher WTP	More likely to pay when there are co-benefits
Rice et al. (2020)		Females have higher WTP	
Ritchie et al. (2021)	Pro-environmental behaviour increases likelihood to offset. Higher degree of altruism increases WTP	WTP decreases with age	WTP more to support local offsetting programs than international; frequent flyers less likely to offset
Rotaris et al. (2020)	Higher environmental concern increases WTP	WTP decreases with age; Increases with education; Females have higher WTP; Unemployed have lower WTP	Preference for afforestation offsetting projects over improving aircraft and fuel technology
Sanguinetti & Amenta (2022)			
Schwirplies et al. (2019)	Stronger environmental and social preferences increase WTP	WTP increases with income; Decreases with age; No correlation with education	Preference for reforestation projects over renewable energies projects and local projects over international
Seetaram et al. (2018)		WTP decreases with age; increases with employment	
Shaari et al. (2020)		WTP increases with income, age, education, employment; No correlation with gender	
Shaari et al. (2022a)	Knowledge about emissions from aviation increases WTP		
Sonnenschein & Mundaca (2019)			Higher WTP for mandetory surcharge than VCO
Sonnenschein & Smedby (2019)	Sense of personal responsibility for climate change mitigation increases WTP	WTP increases with income; Females more likely to offset	Preference for using funds for climate change mitigation or sustainable transport solutions
Zhang et al. (2022)		WTP increases with income, education; Decreases with age; Females more likely to offset	Preference for domestic offset projects; WTP more for co-benefits

6. Discussion

The analysis in this thesis identified several elements that influence an individual's WTP to offset carbon emissions from air travel through the use of a meta-regression paired with a qualitative, within-study analysis. This section will discuss the findings in depth, providing interpretations and implications concerning the ex-ante hypotheses that were articulated in Section 3, as well as other interesting findings. Moreover, practical applications, limitations and opportunities for future research will be identified.

6.1 Hypothesis testing

The first hypothesis is that WTP is positive and increases with income based on economic theory that suggests the act of offsetting is a normal good (Andreoni, 1990). The mean WTP identified in the primary studies is $103 or $72 per tCO_2, depending on the sampling method used, thus confirming the expectation of a positive WTP. In the meta-regression, income did not have statistical significance in all but one variation, although it did always have a positive coefficient. However, within the primary studies themselves, noted in Table 6, many reported that WTP increased with income, or that higher-income individuals were more likely to participate in an offsetting scheme. A potential reason why these results were not found in the meta-regression is that the estimates were drawn from studies that typically did not provide separate WTP estimates for different income groups, but rather, for the sample's mean. Notwithstanding, if there were more studies available for the meta-analysis, a wider range of incomes would likely appear and allow for the relationship to be seen.

The second hypothesis predicts that WTP would be affected by the payment vehicle of the offsetting scheme. One perspective suggests that a voluntary program would increase WTP due to the warm glow benefit (Andreoni, 1990; Bishop, 2018; Chilton & Hutchinson, 2000), while another suggests that it would have the opposite effect due to free riding (Kim & Brook, 1984; Liebe et al., 2011; Menges et al., 2005). The results of the meta-regression found no significance, and no comparable trends were found in the qualitative review. Any influence of the payment vehicle may become irrelevant if there were competing relationships from it affecting some people positively and others negatively. Since there were no decisive findings, this hypothesis cannot be accepted, but more research could be conducted to directly compare consumer preferences for voluntary or compulsory offsetting programs.

The third hypothesis states that WTP would increase with the level of credibility of the offset program, which could be indicated by third-party certification or by clear specifications of how the funds will be used. This hypothesis is clearly supported by the meta-regression results. In all model variations, the coefficient for the *Credible* variable is positive and significant at the one percent level, with a magnitude of 58% to 160% depending on the model and sample used. Moreover, many of the studies found that WTP is affected by a respondent's belief in the effectiveness of the offsetting project to adequately reduce emissions. MacKerron et al. (2009) and Zhang et al. (2022) specifically tested for this, and both found that respondents had higher WTP when the carbon offset was certified or accredited than if it was not. Validating the assumption that individuals would perceive an offsetting project to be more effective if the use of the funds was clearly specified, the study by Seetaram et al. (2018) directly compared VCOs that were described to be used for specific environmental projects to other VCOs whose use was generic and verified that WTP was higher for the former. Similarly, Rotaris et al. (2020) found that the description of the offsetting project was one of the most important factors influencing WTP.

The fourth hypothesis anticipates that WTP increases with the level of environmental consciousness, indicated through younger age, higher education, and more recent time. Overall, the condition that WTP would increase with more knowledge and concern for environmental issues is supported, especially based on the qualitative within-study findings for those studies that investigated it, as well as positive findings in the meta-regression for the level of education and the year. However, using age as an indicator does not provide consistent results, and therefore, the assumption that younger individuals exhibit more pro-environmental behaviour may not be accurate.

The fifth hypothesis is that studies using stated preference methods would find higher WTP values than those using revealed preference methods. Only one revealed preference study was found in the literature search and could therefore not be included in the meta-regression since there would be insufficient data points to draw any inferences. However, it is worth noting that the study found that most air passengers in the sample did not purchase the carbon offset, and the average amount paid was only 1 Euro (Berger et al., 2022). In contrast to the mean WTP of \$103 and \$72 per tCO_2 observed in the meta-analysis samples 1 and 2, respectively, it does imply that the revealed preference values are lower than the stated preference values, though this interpretation must be applied with caution since more context is needed.

6.2 Additional meta-regression insights

Based on the results of the meta-regression, there appear to be some differences in WTP between global regions. The regression coefficients represent the change in WTP as compared to Europe, which was used as the reference dummy variable. In several of the model variations, North America (namely the United States as there were no Canadian nor Mexican studies) has a significant, positive coefficient. Additionally, other regions (largely Australia) have a significant, negative coefficient. Since the income and WTP values were adjusted using PPP conversions, it reflects the respondent's purchasing power, and thus the regional differences shown in these results would not be due to income differences between countries. None of the primary studies investigated regional differences, although Blasch and Ohndorf (2015) and Brouwer et al. (2008) both noted lower environmental concern among the American respondents, which is contrary to the meta-regression results; therefore, it is difficult to speculate why the differences exist.

Another significant factor that appeared in the meta-analysis is the distance of the flight, whereby travellers have lower WTP per tCO_2 for long flights than for short flights. This makes sense intuitively, since as the flight becomes longer, more CO_2 is emitted, thus increasing the overall amount that would need to be paid to offset it. This can suggest that the marginal benefit of offsetting emissions is decreasing. Furthermore, Ma et al. (2021) theorise that the relatively higher WTP for shorter flights, which tend to be for domestic as opposed to international travel, is due to respondents feeling more responsibility to offset their carbon footprint in their local region.

Unexpectedly, the meta-regression indicated a significant relationship between WTP and framing the offset to the respondent as "per tCO_2" or "per flight." For the data coding, the WTP values were converted to be consistently measured as per tCO_2, but the variable in the analysis represents how it was presented to the respondent and was initially only coded for self-referencing purposes. However, due to its statistical significance in nearly all variations of the regression models, there appears to be a true influence on the respondent based on how the offsetting scenarios are framed. The negative coefficient means that individuals would pay less if it was framed in tonnes rather than by flight. The reason for this influence is not immediately clear but would likely be related to consumer psychology (White et al., 2019), thus further research would be needed to fully understand the connection.

It should also be noted that the set of study variables were not statistically significant in the primary model, although *Source_journal* became significant with a negative coefficient in most variations of the sensitivity analysis. This observation means that studies published in journal articles yield lower WTP than grey literature, suggesting that journals may tend to be more conservative. The lack of significance for the primary study's model (CV or CE) and whether the primary study included selected relevant variables implies that method choices do not significantly influence stated WTP.

6.3 Discrepancy in carbon offset participation

Interestingly, despite finding that there is a positive WTP, it appears that few people have actually participated in carbon offsetting and have very little knowledge about emissions from aviation. Although most of the studies used stated preference methods to estimate a value, many of them also included survey questions to find out whether the respondents have participated in offsetting schemes before. Several studies found that most respondents did not know anything about carbon offsetting, and even of these individuals, few choose to participate. Cheramakara (2014) and Hagmann et al. (2015) both found that approximately one-third of respondents had heard of offsetting schemes, but of these, only 23% of respondents in Hagmann et al.'s study had participated before, while none of Cheramakara's had. Likewise, the study by Araghi et al. (2016) found only 4.6% of respondents stating to have ever contributed to offsetting schemes. In all of the primary studies examined, the largest proportion of respondents who claimed to have offsetting experience was 30% in the study by Choi and Ritchie (2014) in Australia. These observations are consistent with the revealed preference study by Berger et al. (2022) in Switzerland, which confirmed that most of the air passengers did not purchase offsets at all. The discrepancy between the stated WTP and the actions taken can be explained by the attitude-behaviour gap that is commonly found in environmental goods (Babutsidze & Chai, 2018; Farjam et al., 2019; Higham et al., 2016; Taufique et al., 2017). Theorised reasons for this gap include an individual's prioritisation of other needs or wants and the belief that they cannot influence the situation (Blake, 1999; Kollmuss & Agyeman, 2002).

6.4 Implications for business practice and public management

Understanding how consumers value mitigating their air travel emissions can provide insights for practical applications. Considering the substantial impact aviation emissions have on the environment (ICAO, 2019), there is an opportunity for offsetting programs to make a notable difference. One of the ways to approach emissions mitigation is through carbon taxes or mandatory surcharges; therefore, policymakers can use the results to align their policies with consumers' preferences to support successful implementation (Alfaro & Chankov, 2022). The current pricing for regulatory carbon markets and carbon taxes ranges from \$61 per tCO_2 to \$122 per tCO_2 globally (World Bank, 2023b), which closely aligns with the mean WTP identified in this analysis of \$72 per tCO_2 to \$103 per tCO_2.

Additionally, airlines can use the findings to increase the number of travellers that choose to contribute to their voluntary offset programs. An important finding from this analysis is that air travellers are willing to pay to offset their emissions, yet most admit to not having done so. The median price of a VCO is \$15 per tCO_2 (Zelljadt, 2016), which is substantially lower than the mean WTP identified. This imbalance implies that the current VCO structures are ineffective and do not take full advantage of the potential for emissions mitigation. One method that could be used by airlines to increase the number of passengers who offset is switching to an opt-out model instead of an opt-in model. A study by Araña and León (2013) found that a larger proportion of individuals will participate in carbon offsetting if it is framed as the default option rather than as an optional add-on. Moreover, the results of the meta-regression showed that there can be a 160% increase in WTP if the offsetting program is perceived as credible. This is also substantiated in a study by Liu et al. (2023) that found that air travellers are more likely to contribute to a VCO when the specific actions that will be taken to offset are emphasised. Therefore, it is critical that the air traveller understands and trusts the offsetting program, which can be done through certification and clear communication that describes how the funds will be used to mitigate emissions.

6.5 Limitations and future research

This analysis of consumer WTP for air travel emission reduction is subject to certain limitations. In terms of the existing research on the topic, the most notable constraint is the relatively low sample size, with only 31 primary studies available for inclusion. Although this is a common occurrence in meta-analyses (Nelson & Kennedy, 2009), the analysis could benefit from a broader range of primary studies. Additionally, there is an uneven geographical distribution of the studies – almost half were conducted in European countries, while only three took place in the United States. However, according to the World Bank (2023a) travel data, the United States had 23% more air travel passengers than the European Union in 2019, indicating that it is a prominent market in the aviation industry, thereby justifying the need for more research. Furthermore, only one revealed preference study has been performed on this topic at the time of writing. It would have been interesting to include it in the meta-regression had there been more revealed preference studies available. Currently, more and more airlines are offering VCO programs, thus opening a substantial market for carbon offsetting and presenting a good opportunity for future research.

Moreover, the meta-analysis could be developed with further analysis. Several other econometric techniques can be used in meta-analysis as an alternative to WLS regression, such as hierarchal or panel-data approaches (Nelson & Kennedy, 2009); therefore, utilising alternative methods could enhance the robustness of the analysis. It would also be interesting to see how consumer preferences for offsetting emissions from air travel compare to other modes of transportation. Several studies about consumer WTP for emissions mitigation for road travel have been conducted, such as those by Achtnicht (2012), Hackbarth and Madlener (2016), Potoglou and Kanaroglou (2007), and Rotaris and Danielis (2019). Therefore, the scope of the meta-analysis could be expanded to include all modes of transportation.

7. Concluding remarks

The objective of this thesis was to understand how consumers value mitigating emissions from air travel. Specifically, the aim was to identify how much consumers are willing to pay to reduce emissions, what factors affect a consumer's valuation, and what determines the study-to-study variation. A meta-analysis was performed using 31 primary studies that reported estimates of WTP to offset or reduce aviation emissions. The results from each primary study were converted to a common measurement and used in a WLS regression analysis to identify the factors that influence the WTP. Synthesising and analysing the previous studies in this way provides insights that enable policymakers and airlines to implement offsetting programs that will be supported by consumers and make a true impact on mitigating GHG emissions.

The results of the meta-analysis reveal that there is a wide range of WTP values, with a mean of $72 or $103 per tCO_2, depending on the sampling method used. The variation in WTP values across studies can be explained by several key factors. One of the most important influences is the credibility of the carbon offset scheme, which was found to increase WTP by up to 160% over an uncredible program. Interestingly, WTP was also found to be higher if the offset was framed to the respondent in terms of "per flight" rather than "per tCO_2." However, no relationship was identified between WTP and whether the offset scheme was voluntary or compulsory. Consumers' WTP per tCO_2 was found to decline as the flight distance increases, presumably due to the absolute payment amount increasing. Moreover, some consumer characteristics were also found to affect their WTP. Higher income, more education, and pro-environmental attitudes were all found to increase WTP, while age and gender do not appear to have a consistent influence. Finally, some of the regression models used found that WTP values increase over time, with increases of six to seven percent per year. Regarding study-to-study variation, no correlation was identified between WTP and the primary study's use of CV versus CE methods. However, there is some evidence to suggest that WTP is near zero in actual consumer actions, highlighting the attitude-behaviour gap and the need to improve the current offsetting structures to encourage consumers to turn their intentions into action.

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Appendix A: List of studies identified and screened

Reference	Included	Reason for exclusion
Akter et al. (2009)	Yes	
Alberini et al. (2018)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Alfaro & Chankov (2022)	Yes	
Álvarez-Gil & Yan (2013)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Amenta & Sanguinetti (2020)	No	Criteria 2: Duplicate of other study (Sanguinetti & Amenta, 2022)
Anand et al. (2021)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Araghi et al. (2016)	Yes	
Baumeister et al. (2022)	No	Criteria 4: Cannot measure effect size
Berger et al. (2022)	Yes	
Blasch & Farsi (2014)	No	Criteria 4: Cannot measure effect size
Blasch & Ohndorf (2015)	Yes	
Brouwer et al. (2008)	Yes	
Carroll et al. (2022)	Yes	
Chen (2013)	No	Criteria 4: Cannot measure effect size
Chen et al. (2022)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Cheramakara (2014)	Yes	
Cheramakara et al. (2014)	No	Criteria 2: Duplicate of other study (Cheramakara, 2014)
Cheung et al. (2015)	Yes	
Choi & Ritchie (2014)	Yes	
Choi (2015)	Yes	
Choi et al. (2018)	Yes	
Cordes (2020)	No	Criteria 4: Cannot measure effect size

Reference	Included	Reason for exclusion
Denstadli & Viesten (2020)	Yes	
Fatihah & Rahim (2017)	Yes	
Fukuyama et al. (2011)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Gabor (2022)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Hagmann et al. (2015)	Yes	
Hausmann et al. (2022)	No	Criteria 3: Full text not available
Heintzman (2021)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Hinnen et al. (2017)	Yes	
Horio et al. (2016)	No	Criteria 3: Full text not available
Hortaçsu et al. (2021)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Hwang & Choi (2017)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Hwang et al. (2019)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Jou & Chen (2015)	Yes	
Kallbekken & Sælen (2021)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Khand (2018)	No	Criteria 4: Cannot measure effect size
Koistinen et al. (2013)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Korba et al. (2022)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Kühne et al. (2021)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.

Reference	Included	Reason for exclusion
Lai et al. (2022)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Larsson et al. (2020)	No	Criteria 4: Cannot measure effect size
Li (2023)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Lim & Yoo (2014)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Liu et al. (2023)	No	Criteria 4: Cannot measure effect size
Lu & Shon (2012)	Yes	
Lu & Wang (2018)	No	Criteria 4: Cannot measure effect size
Ma et al. (2021)	Yes	
MacKerron et al. (2009)	Yes	
Mendes & Santos (2008)	No	Criteria 4: Cannot measure effect size
Murray (2009)	No	Criteria 3: Full text not available
O'Garra & Fouquet (2022)	No	Criteria 4: Cannot measure effect size
Perl et al. (1997)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Qin et al. (2019)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Ragbir et al. (2021)	No	Criteria 4: Cannot measure effect size
Rice et al. (2020)	Yes	
Ritchie et al. (2021)	Yes	
Robinson et al. (2023)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Rotaris et al. (2020)	Yes	
Sanguinetti & Amenta (2022)	Yes	
Schwirplies et al. (2019)	Yes	
Seetaram et al. (2018)	Yes	

Reference	Included	Reason for exclusion
Seraj (2012)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Shaari et al. (2020)	Yes	
Shaari et al. (2022a)	Yes	
Shaari et al. (2022b)	No	Criteria 2: Duplicate of other study (Shaari et al., 2022a)
Shrivastava et al. (2019)	No	Criteria 3: Full text not available
Sonnenschein & Mundaca (2019)	Yes	
Sonnenschein & Smedby (2019)	Yes	
van Birgelen et al. (2011)	No	Criteria 4: Cannot measure effect size
Vongtharawat et al. (2019)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Wang & Jiang (2022)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Whitmarsh et al. (2020)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Winter et al. (2021)	No	Criteria 4: Cannot measure effect size
Xu et al. (2022)	No	Criteria 4: Cannot measure effect size
Yang & Solgaard (2015)	No	Criteria 1: Does not pertain to consumer WTP for emissions reduction or carbon offsetting from air travel.
Zhang et al. (2019)	No	Criteria 4: Cannot measure effect size
Zhang et al. (2022)	Yes	
Zhou & Zhang (2020)	No	Criteria 3: Full text not available
Þorsteinsdóttir (2023)	No	Criteria 4: Cannot measure effect size

Appendix B: Preliminary regression results

	Dependent variable:					
	Log_WTP					
	Sample 1			Sample 2		
	(1)	(2)	(3)	(1)	(2)	(3)
Explanatory variables:						
Year_study	0.230** (0.108)	0.016 (0.025)	0.098*** (0.027)	0.106 (0.163)	0.022 (0.045)	0.142*** (0.048)
Region_NAmerica	-2.094** (0.940)	0.991*** (0.362)	1.453*** (0.369)	0.549 (1.268)	0.854* (0.484)	0.676 (0.620)
Region_Asia	0.037 (0.419)	0.095 (0.308)	0.297 (0.386)	-0.410 (0.766)	0.149 (0.410)	-0.149 (0.722)
Region_Other	-2.980*** (0.357)	-1.478*** (0.221)	-0.730*** (0.239)	-1.804*** (0.627)	-1.382*** (0.319)	-0.401 (0.430)
Distance_long	-1.161*** (0.117)	-1.009*** (0.121)	-0.780*** (0.164)	-0.923*** (0.160)	-0.838*** (0.147)	-0.680** (0.293)
Log_income	-0.467 (0.328)	0.154 (0.273)	0.443 (0.295)	-0.239 (0.523)	0.087 (0.369)	0.050 (0.483)
Age	0.032* (0.016)	0.030** (0.015)	0.009 (0.014)	0.013 (0.025)	0.017 (0.020)	0.016 (0.026)
Female	-0.718 (1.731)	0.230 (1.541)	-0.361 (0.870)	-0.442 (2.005)	-0.706 (1.732)	-0.360 (1.501)
Higher_edu	2.703*** (0.588)	1.369** (0.559)		0.600 (1.118)	0.618 (0.948)	
Credible	0.999*** (0.158)	0.957*** (0.155)	0.335* (0.198)	0.842*** (0.250)	0.810*** (0.235)	-0.048 (0.355)
Voluntary	-0.045 (0.235)	-0.315 (0.224)	-0.422 (0.276)	-0.053 (0.342)	-0.212 (0.304)	-0.034 (0.519)
Unit_tonneCO2	-0.687*** (0.199)	-0.928*** (0.198)	-0.352 (0.250)	-1.306*** (0.442)	-0.985*** (0.345)	-0.495 (0.402)
Direct_reduction	0.313 (0.548)			-0.526 (0.816)		
Cobenefit	1.862*** (0.551)	1.151** (0.489)	1.442* (0.776)	0.122 (1.197)	0.351 (0.605)	0.315 (1.193)
Study variables:						
Model_CE	1.223*** (0.386)	0.036 (0.288)	-0.340 (0.280)	0.626 (0.563)	0.296 (0.418)	-0.117 (0.494)
Year_published	-0.096 (0.113)			-0.032 (0.175)		
Source_journal	-0.432 (0.374)	0.120 (0.275)	-0.214 (0.430)	-0.439 (0.567)	-0.098 (0.403)	-0.581 (0.898)
Incl_education	-2.709*** (0.765)			-1.401 (1.081)		
Incl_age	1.833*** (0.493)			0.666 (0.711)		
Incl_gender	0.033 (0.599)					
Incl_income	0.900** (0.359)			0.493 (0.454)		
Incl_knowledge	-1.408*** (0.313)			-0.101 (0.631)		
Incl_vars		0.125 (0.257)	-0.187 (0.252)		0.023 (0.453)	-0.299736
Constant	-261.537*** (75.269)	-31.586 (49.565)	-197.155*** (52.741)	-143.339 (119.196)	-41.474 (86.747)	-281.035*** (95.946)
Observations	162	162	210	49	49	69
R^2	0.798	0.747	0.443	0.862	0.830	0.351
Adjusted R^2	0.766	0.719	0.400	0.755	0.746	0.168
Residual Std. Error	0.013 (df = 139)	0.015 (df = 145)	0.024 (df = 194)	0.032 (df = 27)	0.033 (df = 32)	0.078 (df = 53)
F Statistic	24.927*** (df = 22; 139)	26.726*** (df = 16; 145)	10.273*** (df = 15; 194)	8.056*** (df = 21; 27)	9.798*** (df = 16; 32)	1.913** (df = 15; 53)
Note:						*p<0.1; **p<0.05; ***p<0.01